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Whittaker et al.

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(45) Date of Patent: Mar. 6, 2012

(54) METHOD AND APPARATUS FOR FIXING A GRAFT IN A BONE TUNNEL

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(73) Assignee: **DePuy Mitek, Inc.**, Raynham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 180 days.

(21) Appl. No.: **12/576,749**

(22) Filed: **Oct. 9, 2009**

(65) **Prior Publication Data**

US 2010/0030222 A1 Feb. 4, 2010

Related U.S. Application Data

(63) Continuation of application No. 11/088,250, filed on Mar. 23, 2005, now Pat. No. 7,655,011, which is a continuation of application No. 10/364,786, filed on Feb. 11, 2003, now Pat. No. 6,958,067, which is a continuation of application No. 09/865,274, filed on May 25, 2001, now Pat. No. 6,517,546.

(60) Provisional application No. 60/275,431, filed on Mar. 13, 2001.

(51) **Int. Cl.**
A61B 17/58 (2006.01)

(52) **U.S. Cl.** **606/98**; 606/185

(58) **Field of Classification Search** 606/185, 606/164, 167, 184, 98, 181; 604/164.12, 604/165.01, 264, 134, 167.05, 167.03, 167.06, 604/164.11; 600/567
See application file for complete search history.

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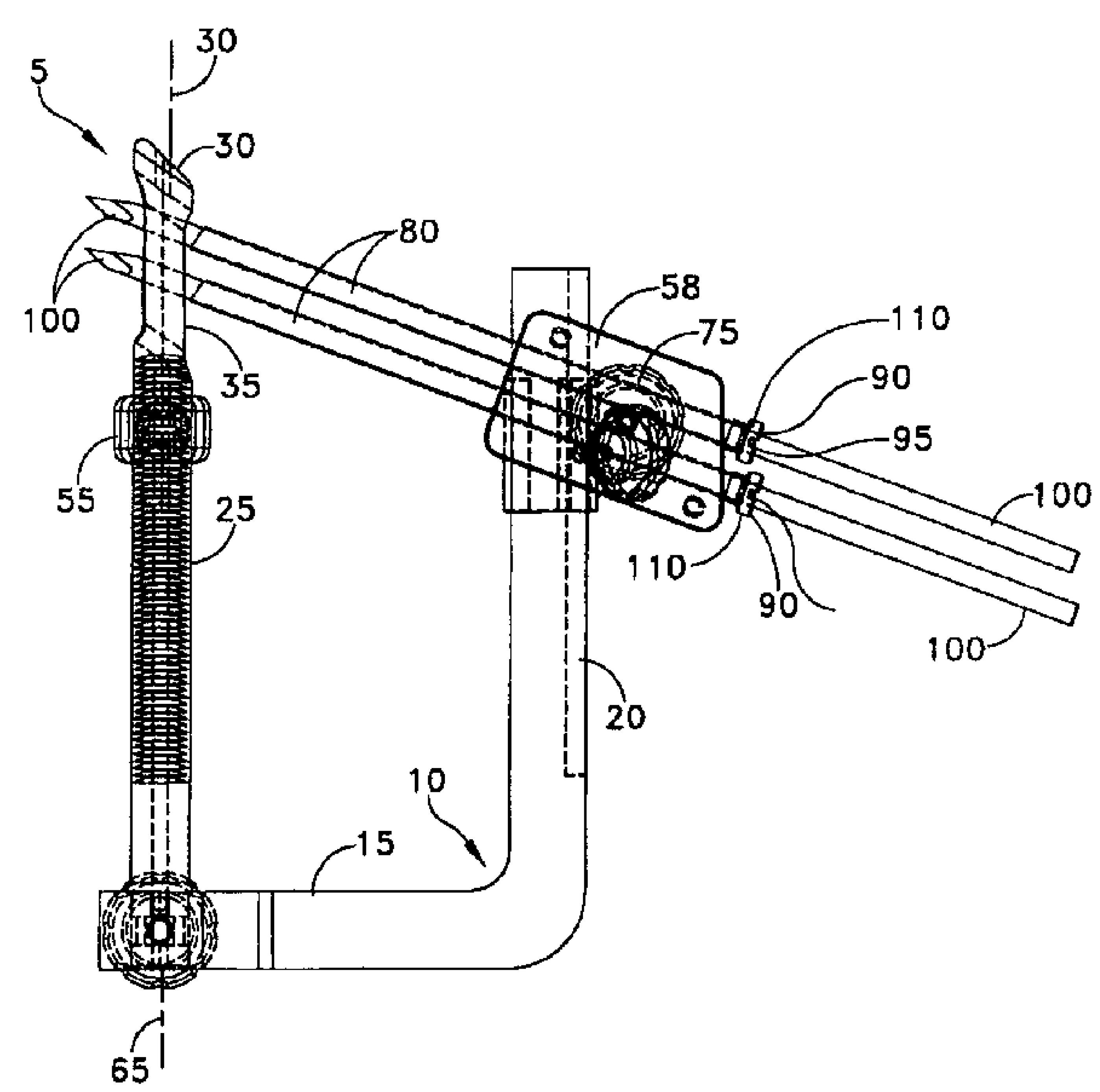
Primary Examiner — Pedro Philogene

(57) **ABSTRACT**

A method and apparatus for fixing a ligament in a bone tunnel by cross-pinning the ligament in the bone tunnel.

14 Claims, 36 Drawing Sheets



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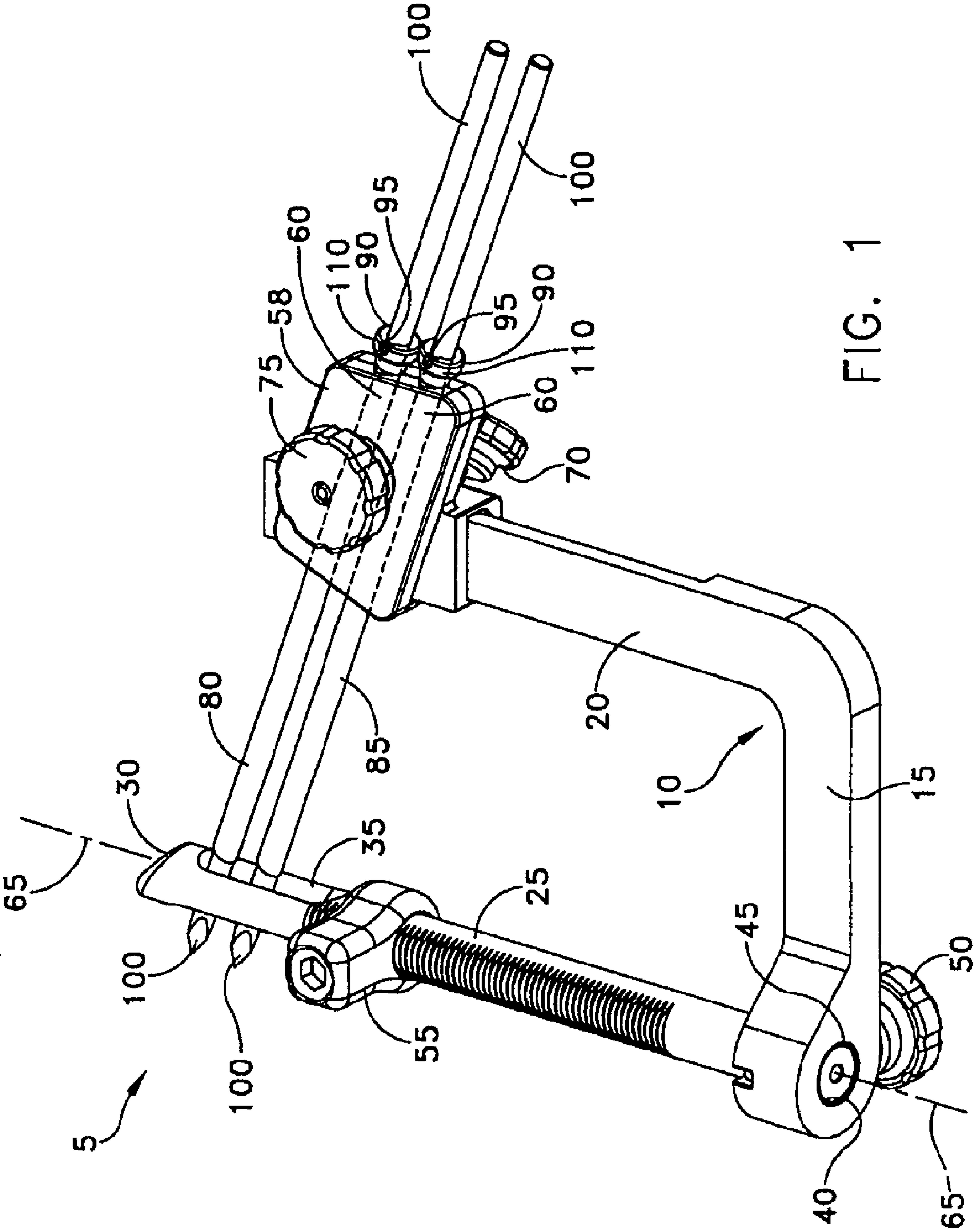
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FIG. 1

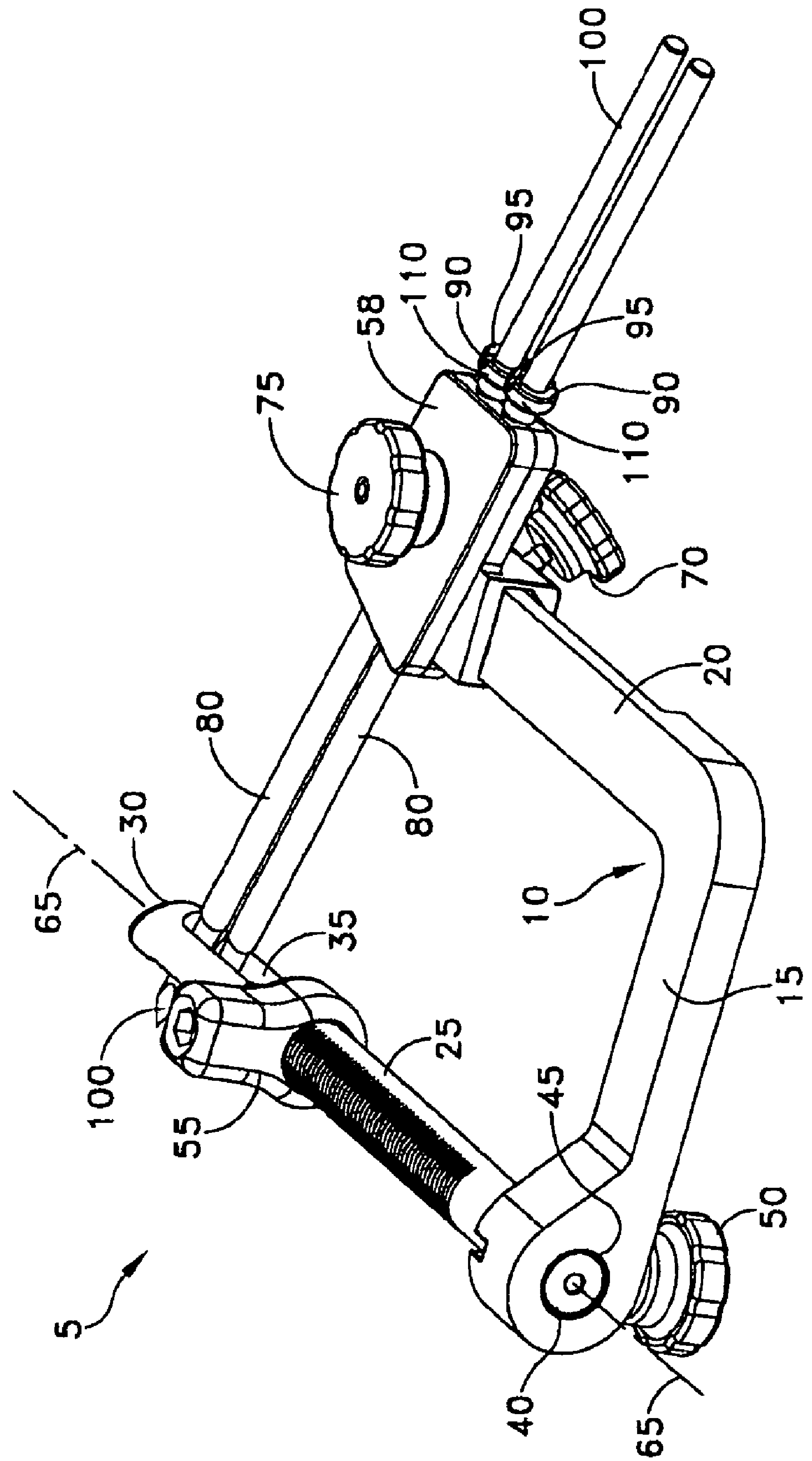
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FIG. 2

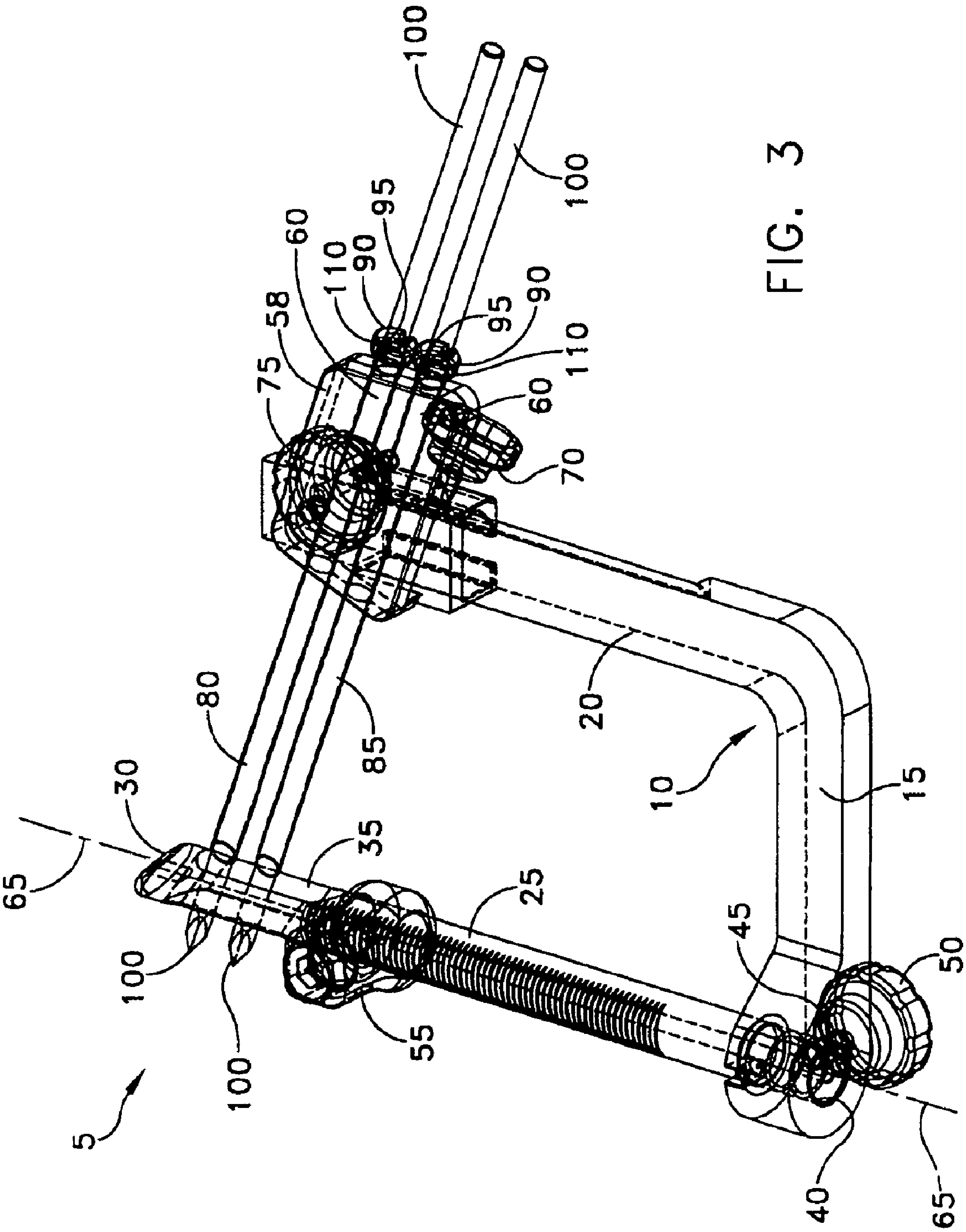
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FIG. 3

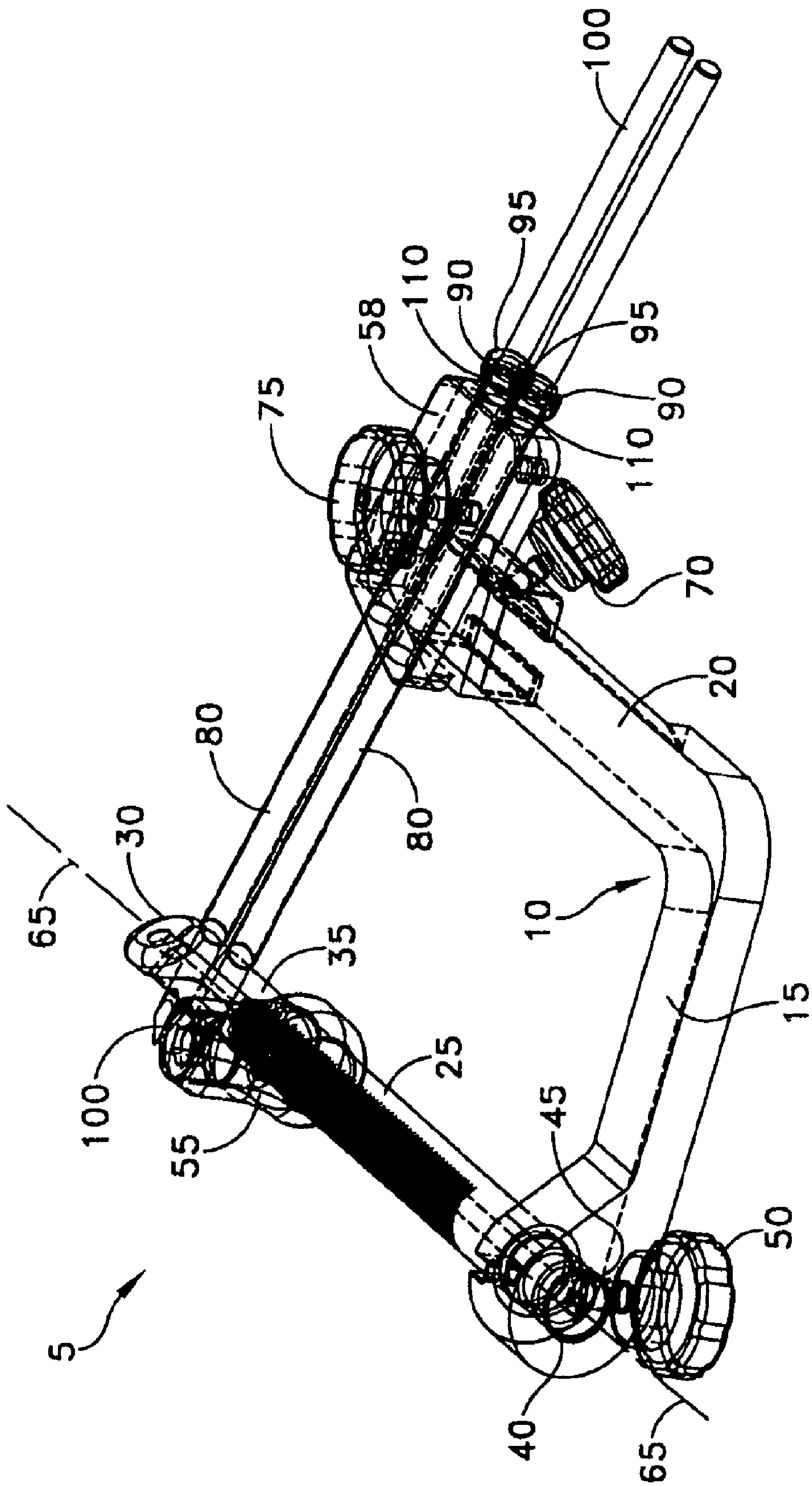
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FIG. 4

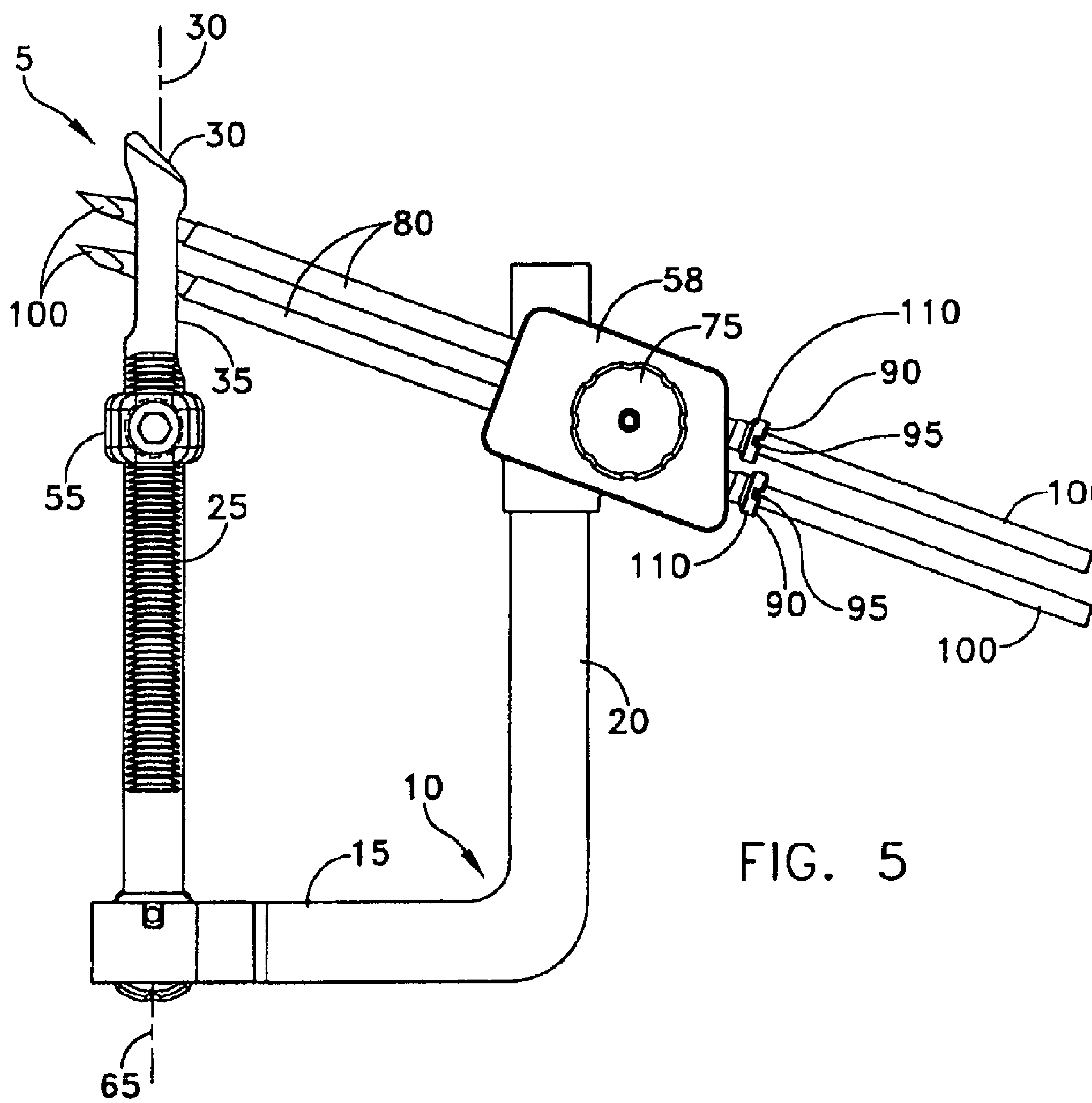
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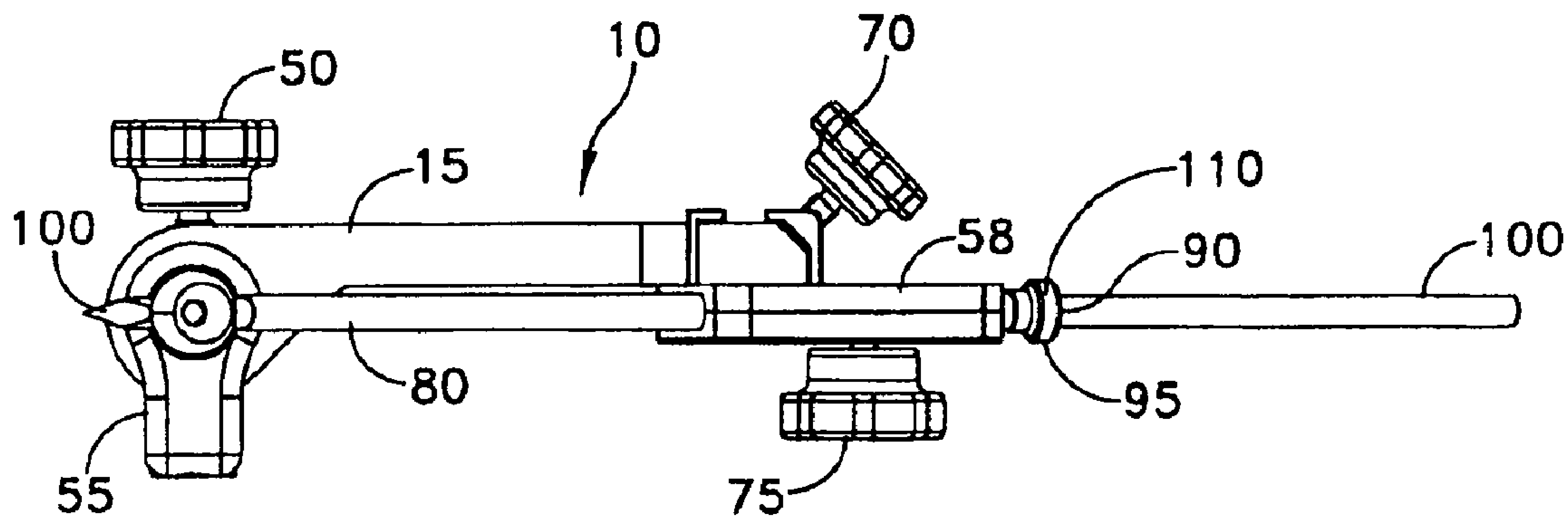
FIG. 5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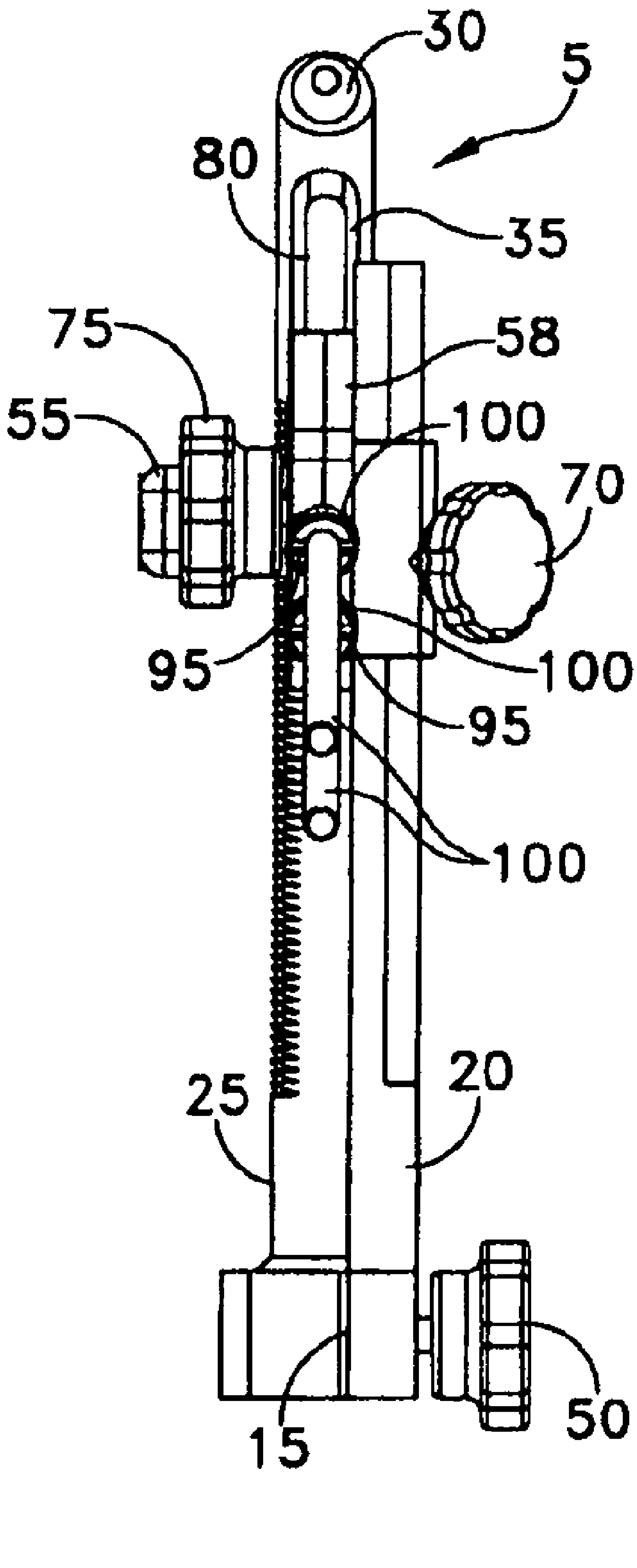

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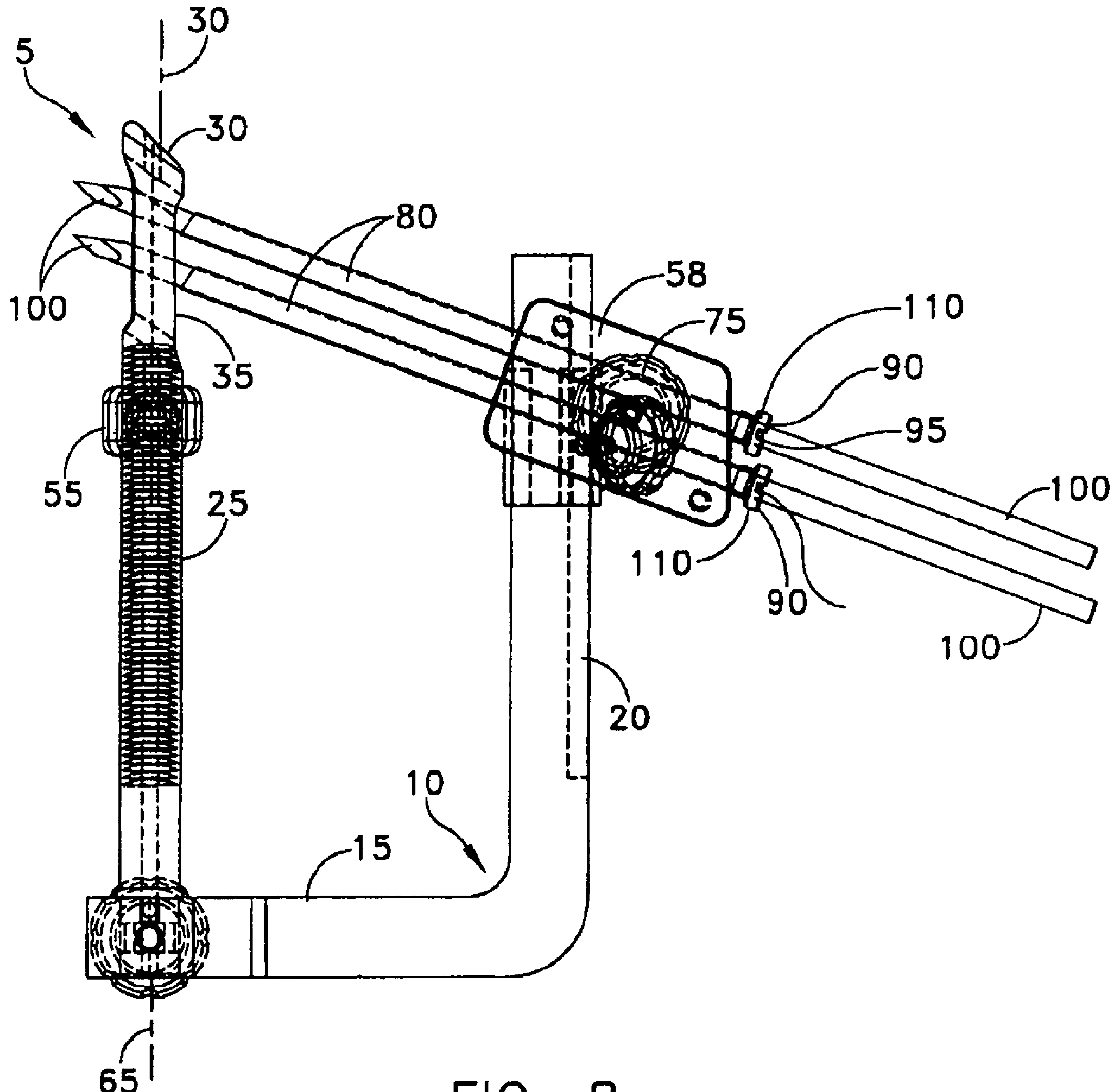

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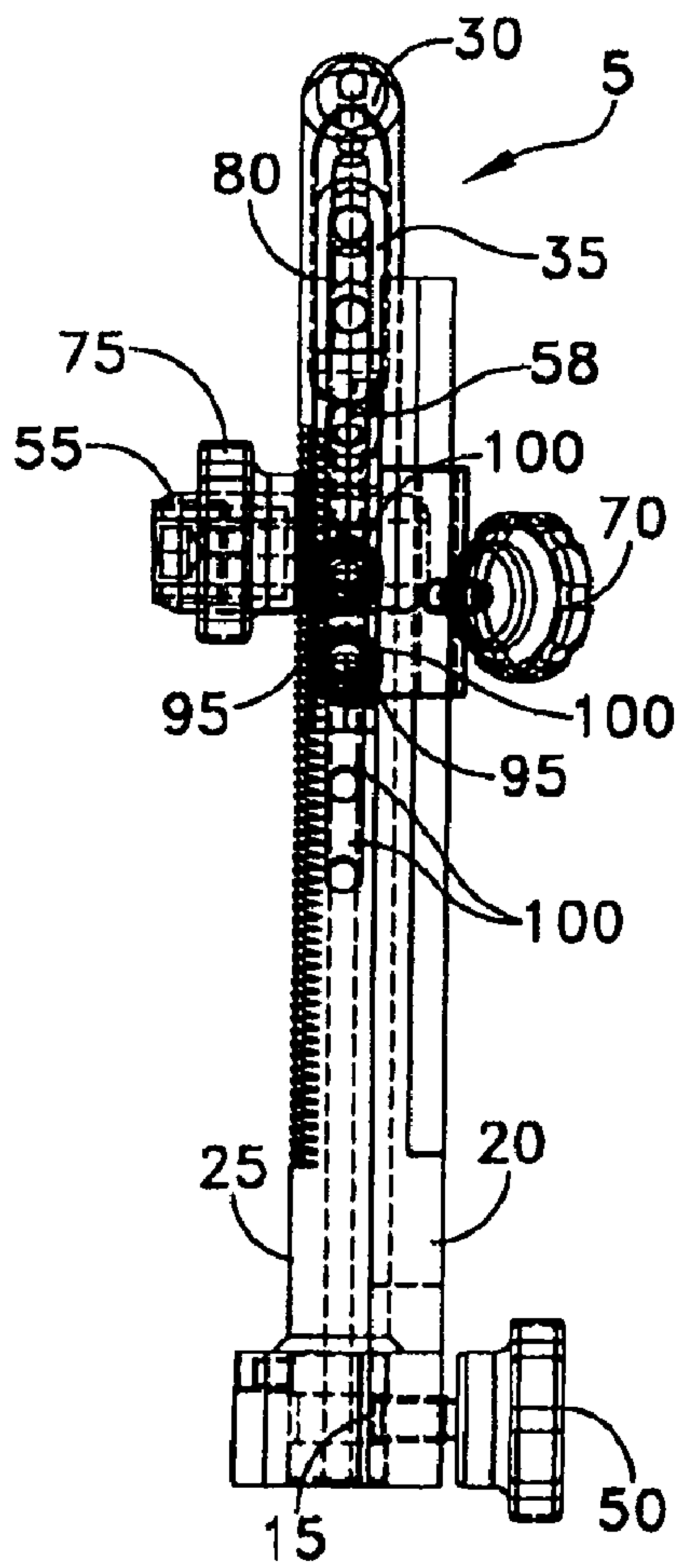
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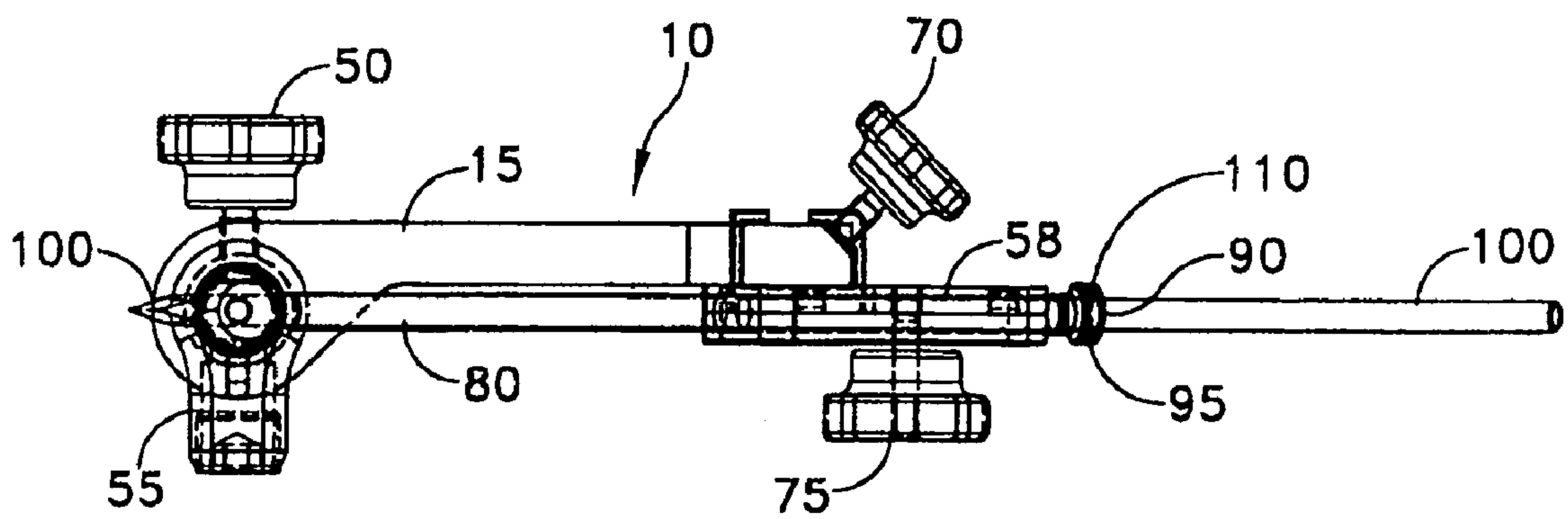
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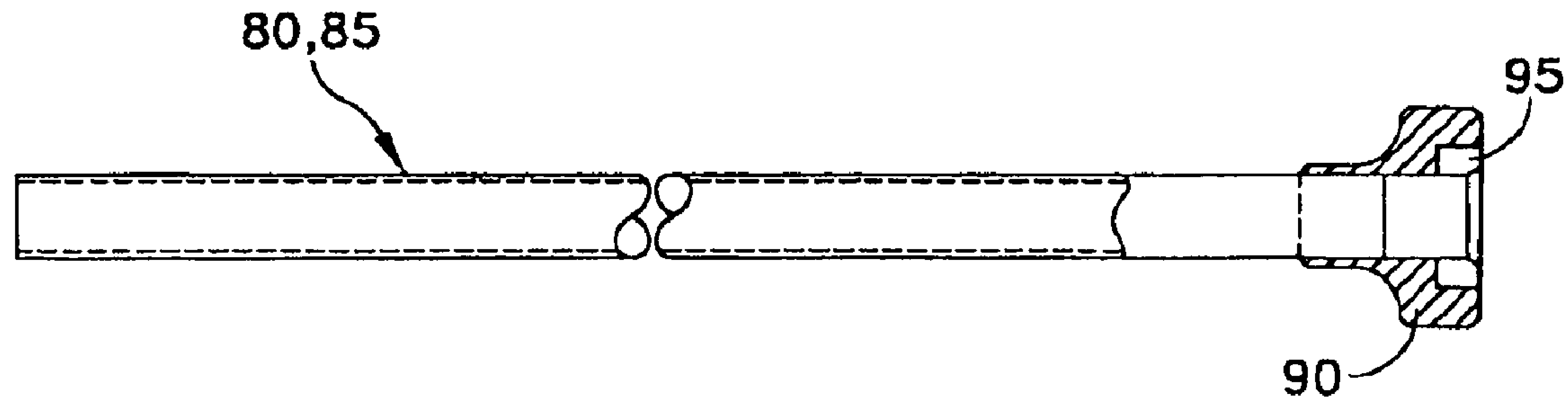

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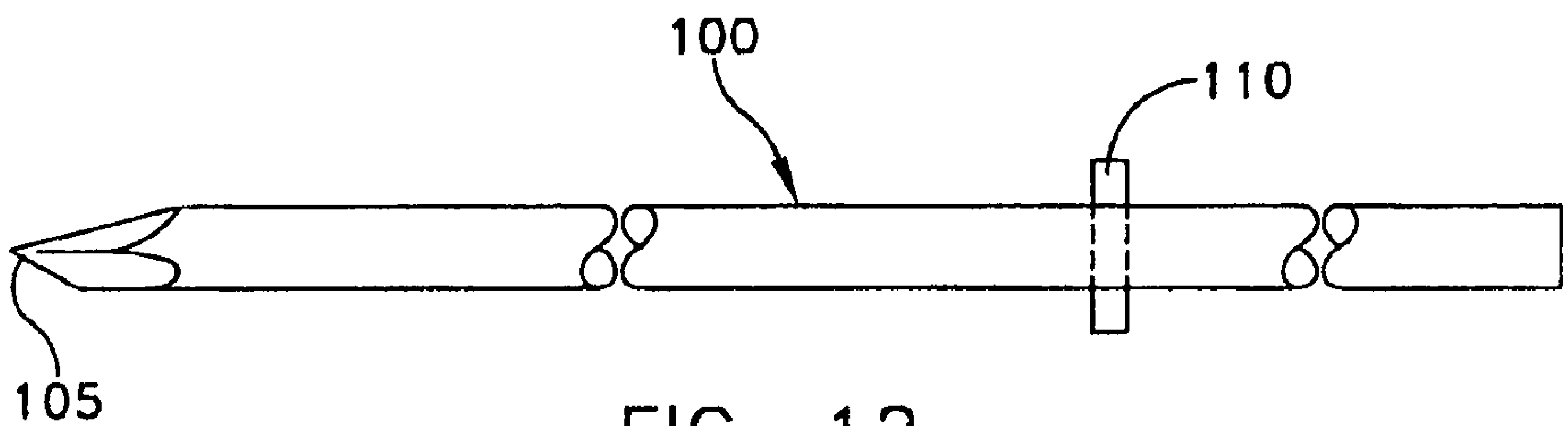

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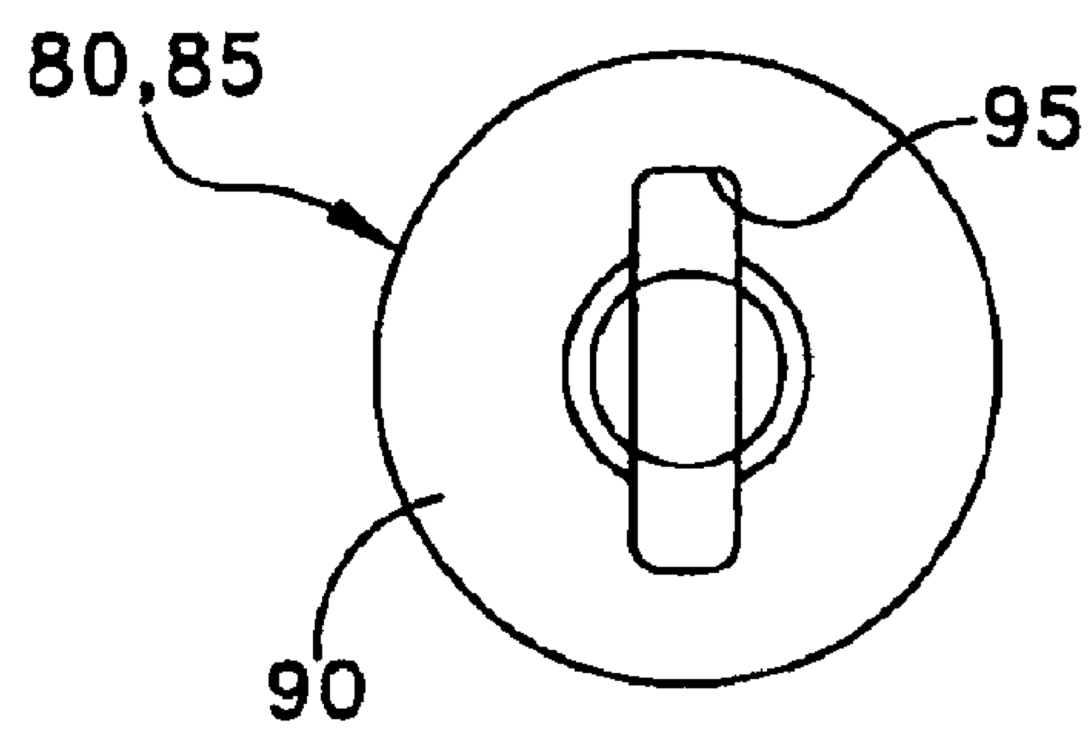

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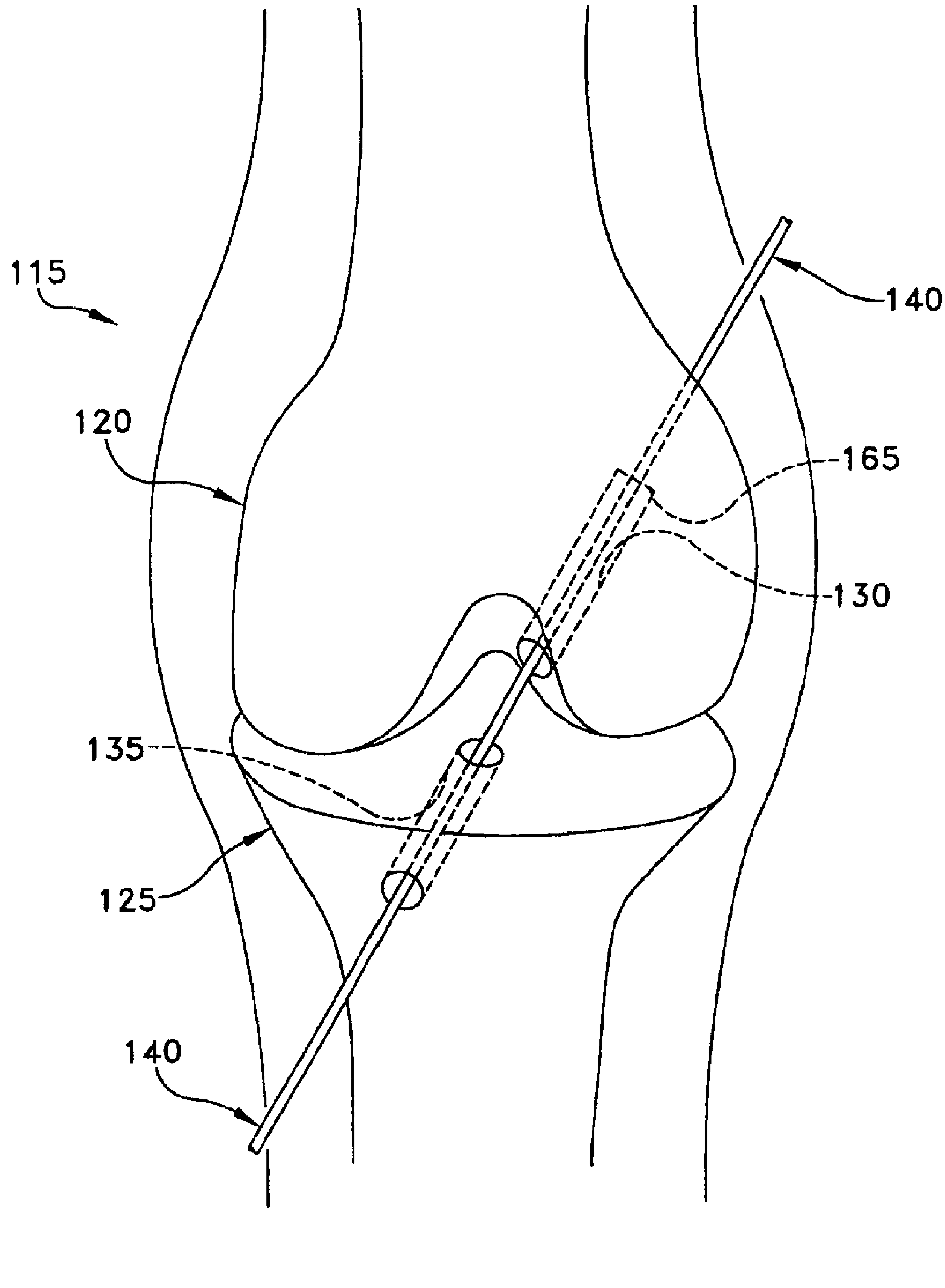

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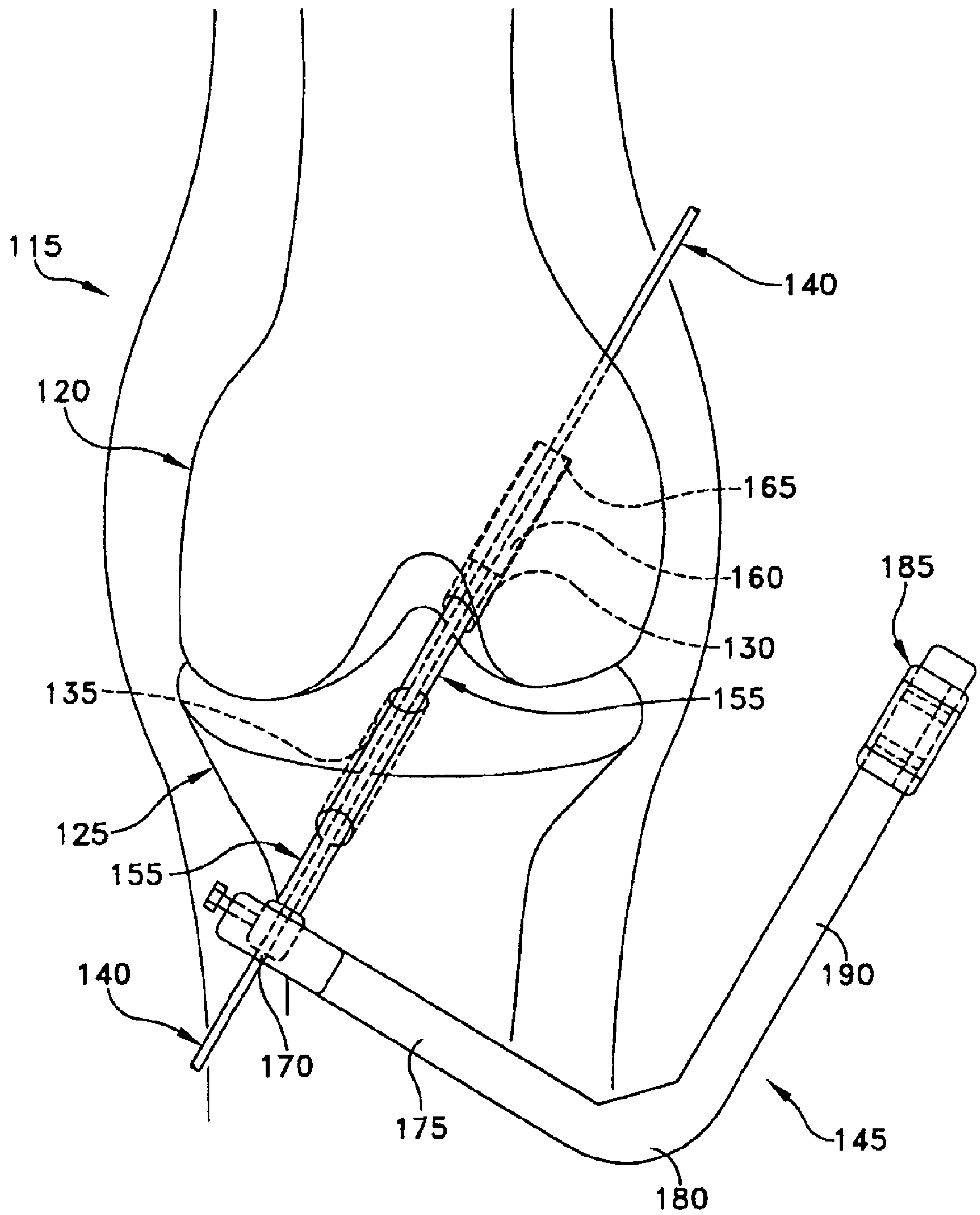
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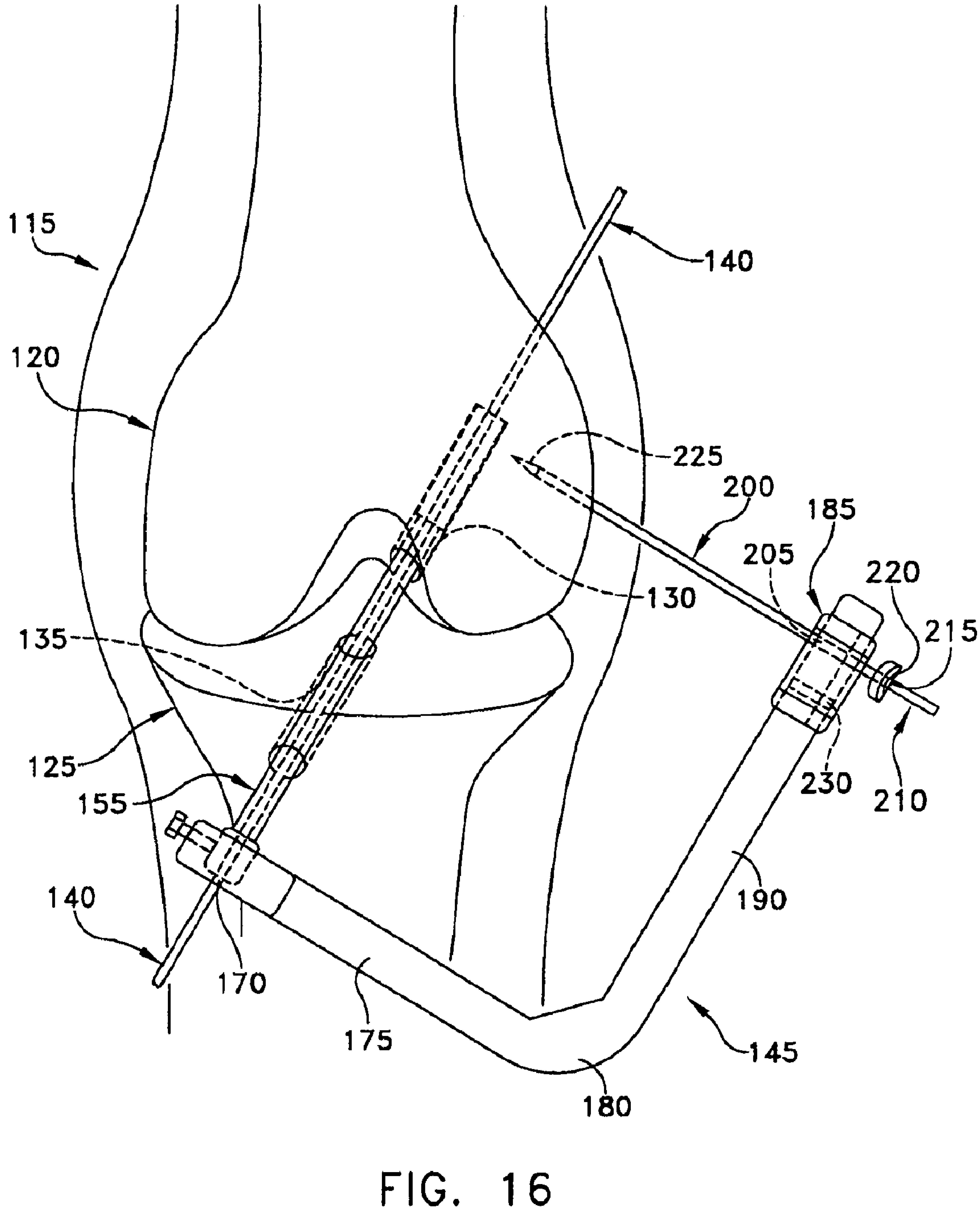
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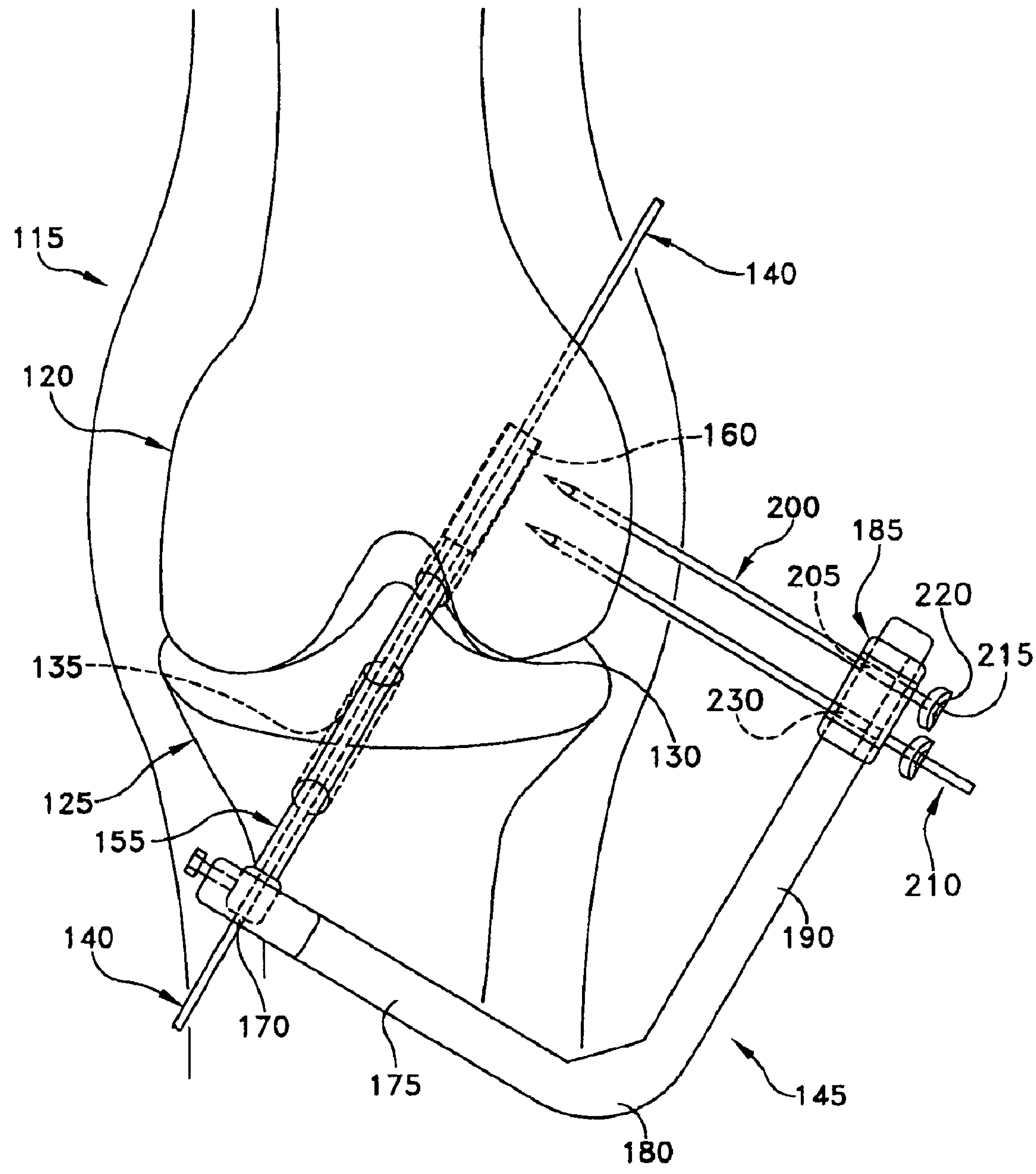
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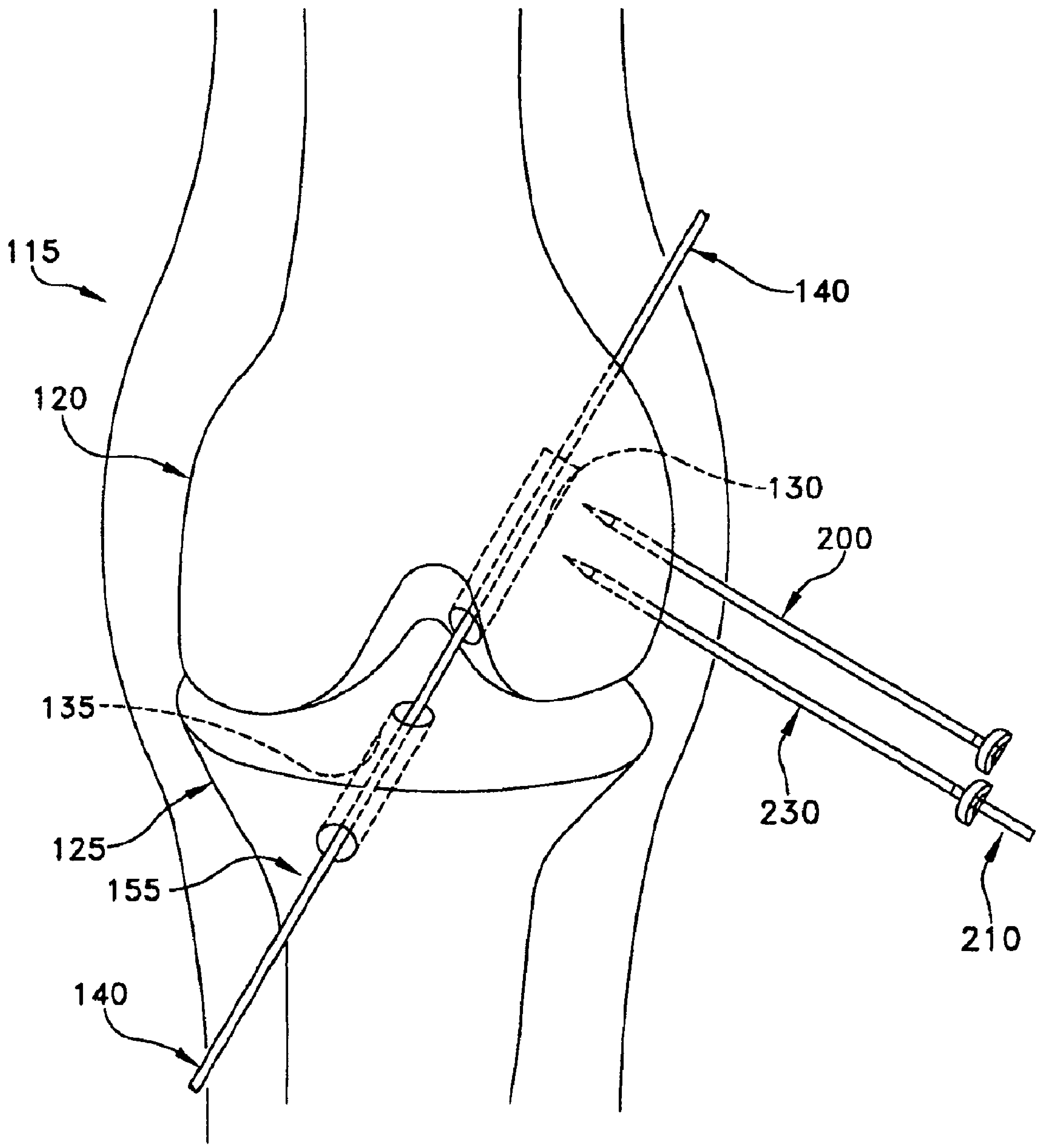

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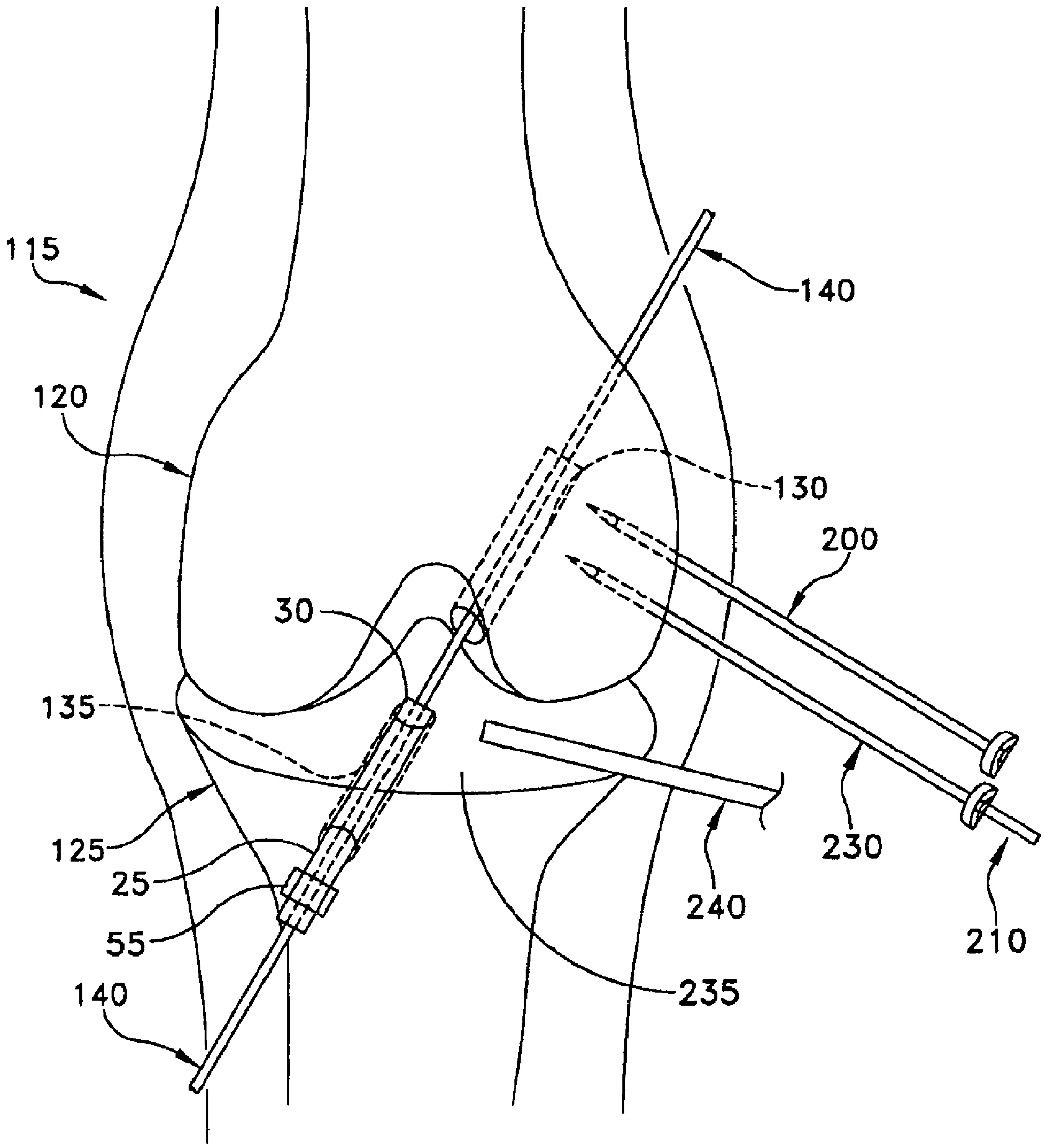

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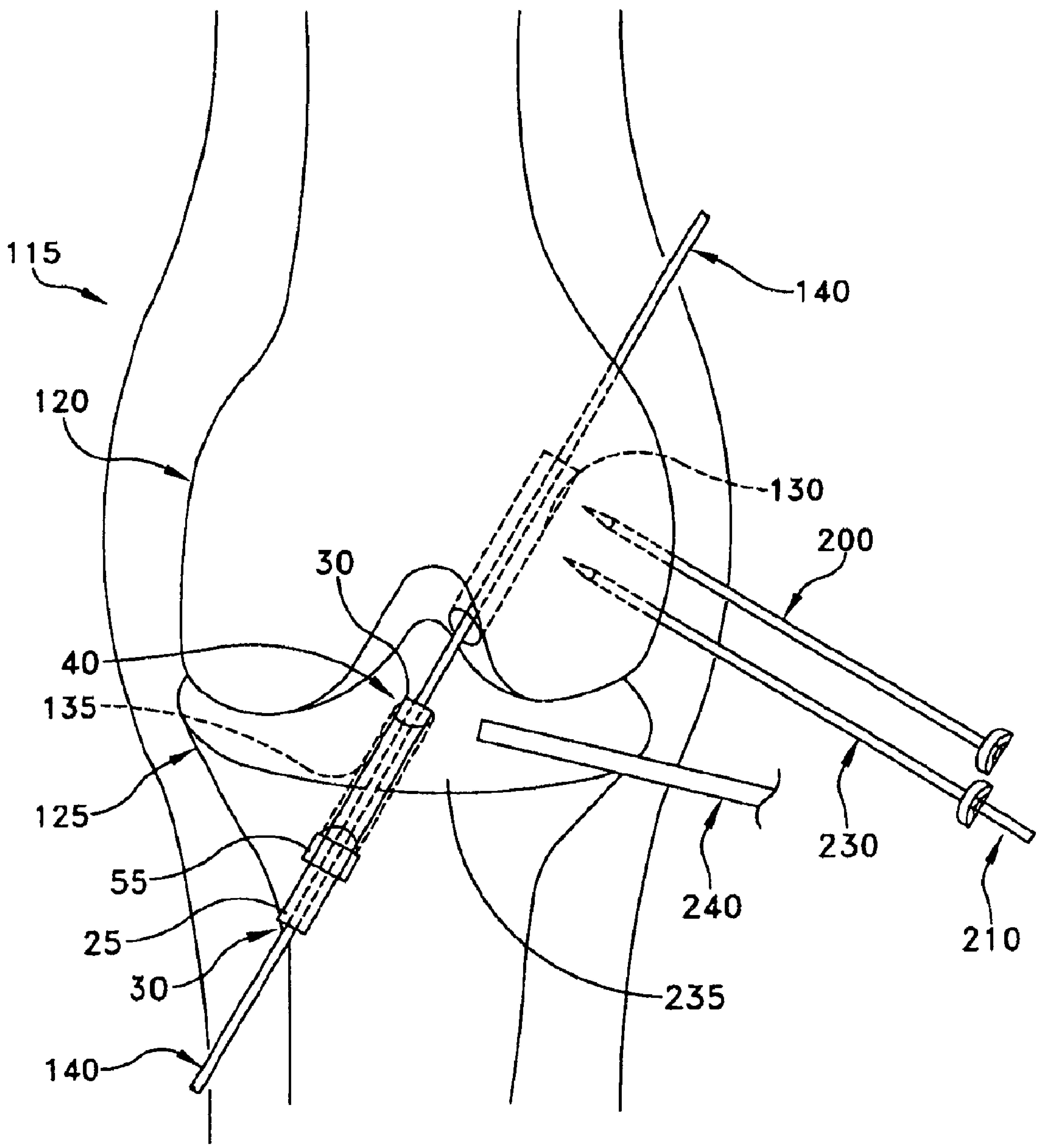

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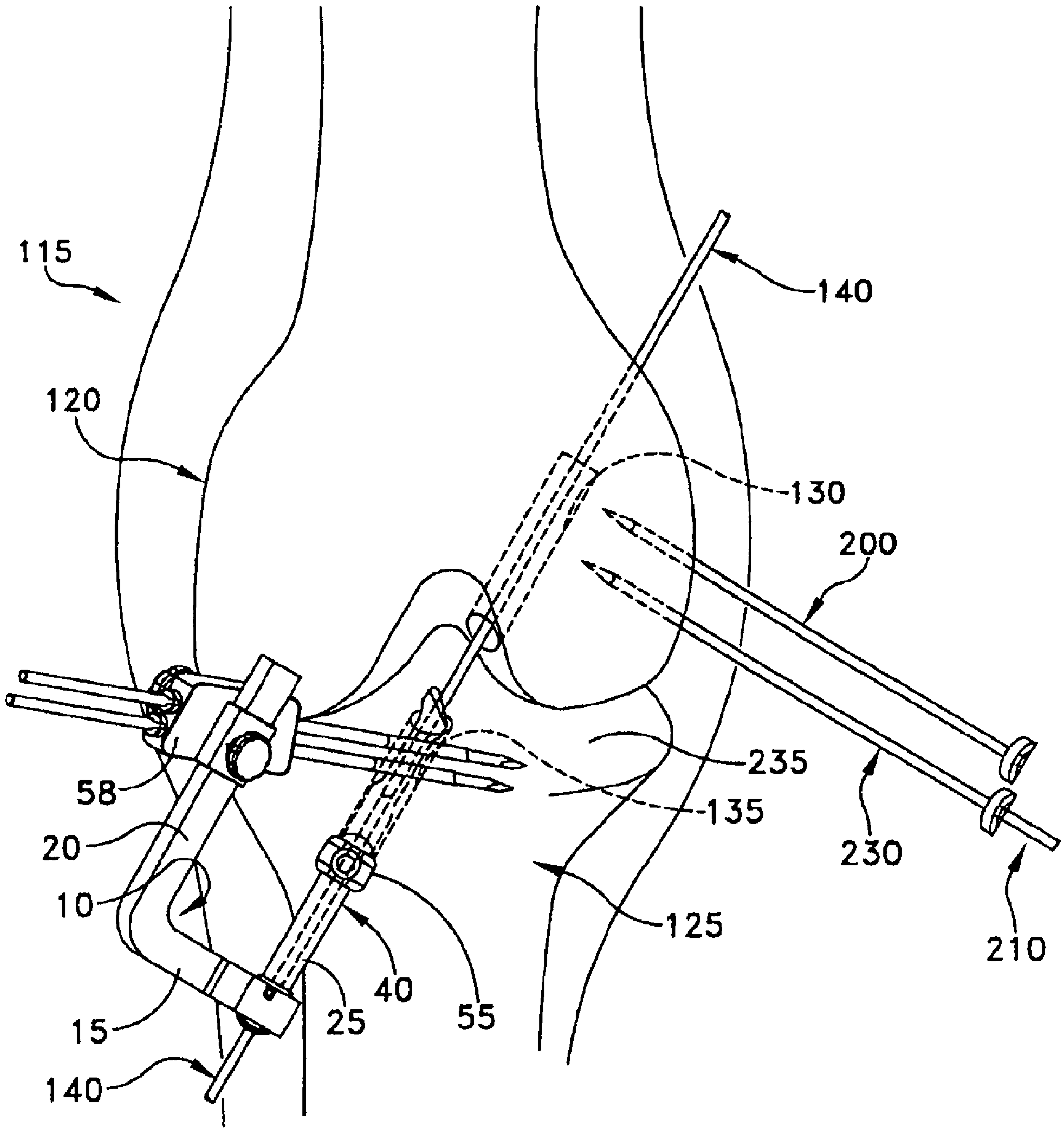

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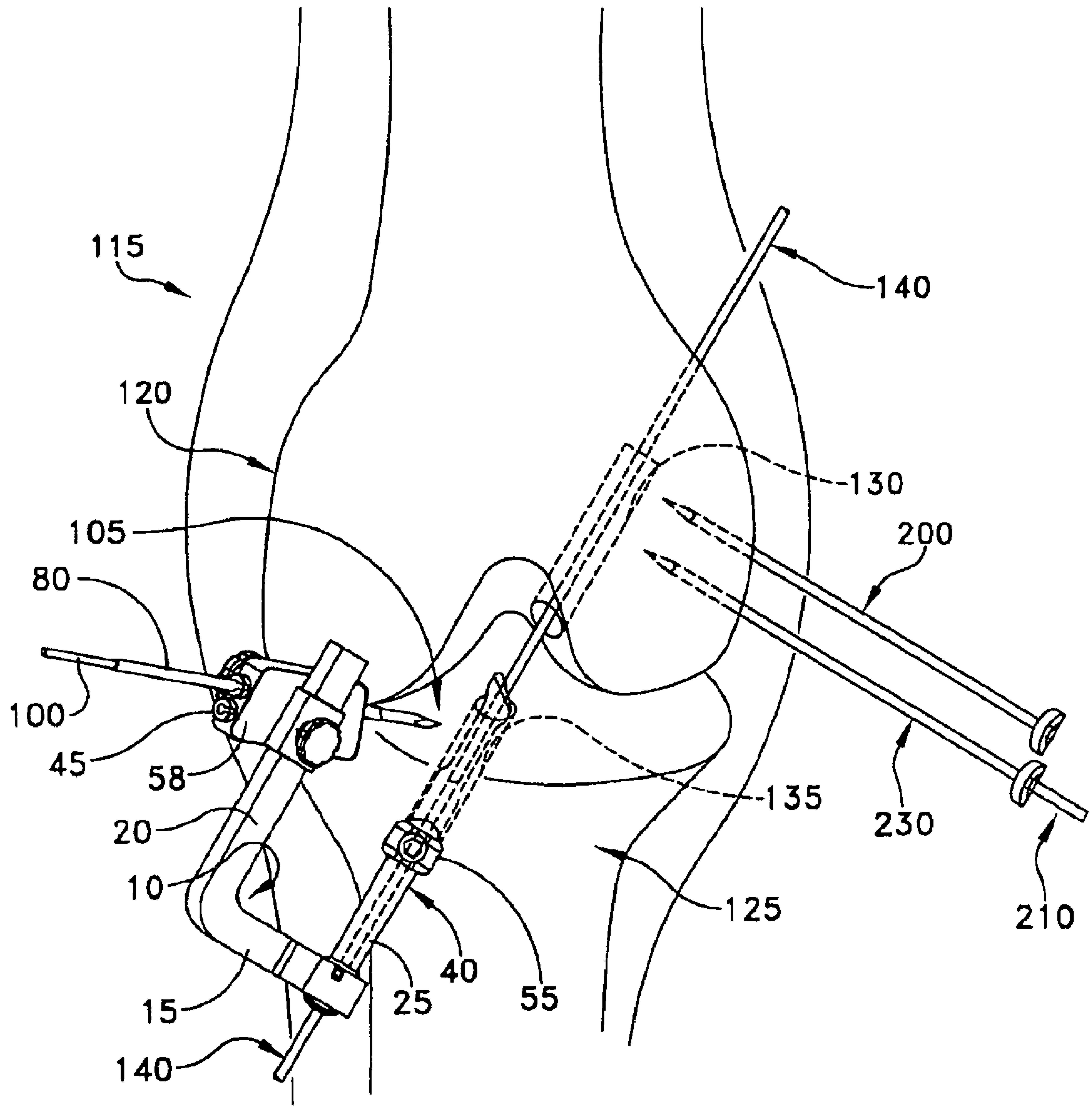
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FIG. 22

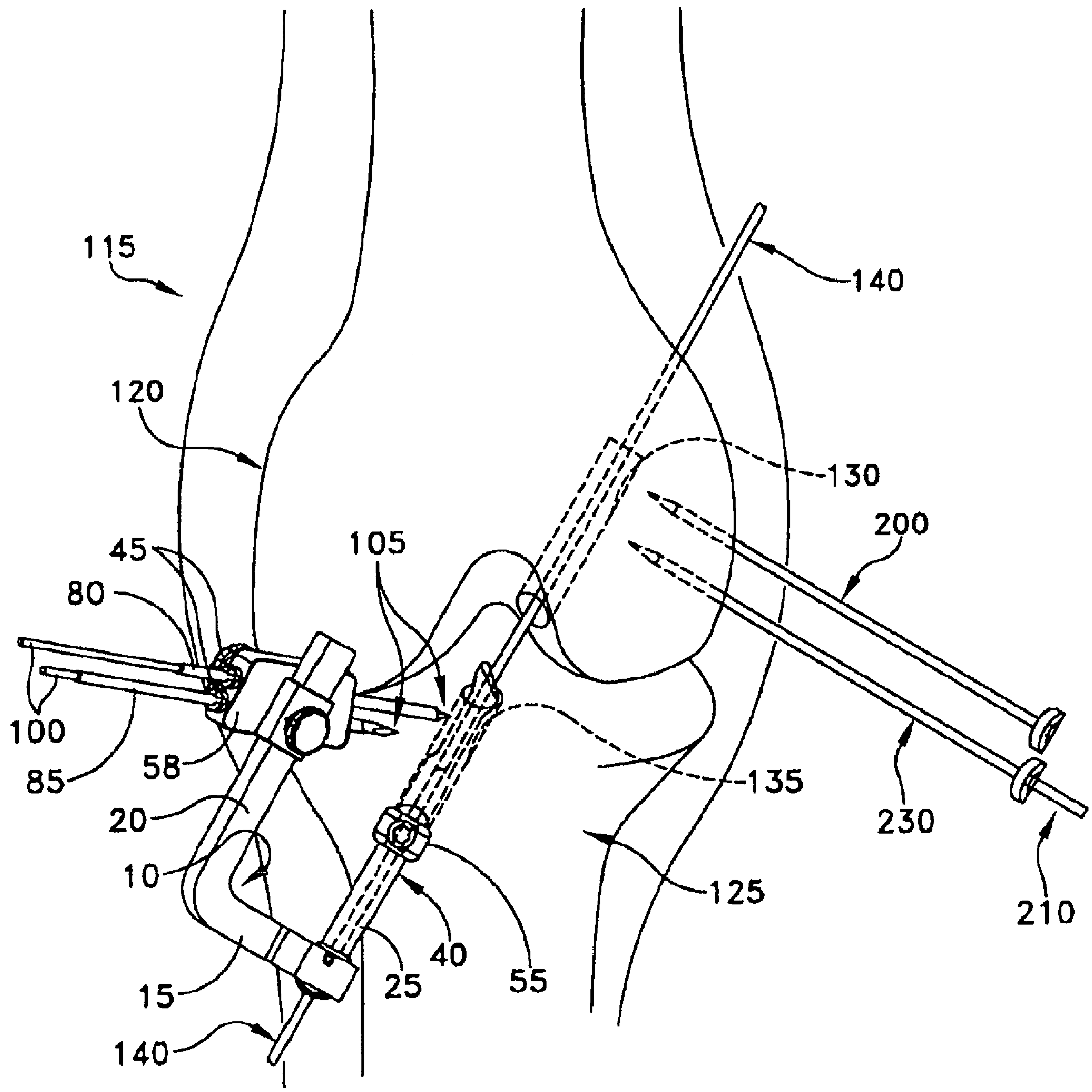
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FIG. 23

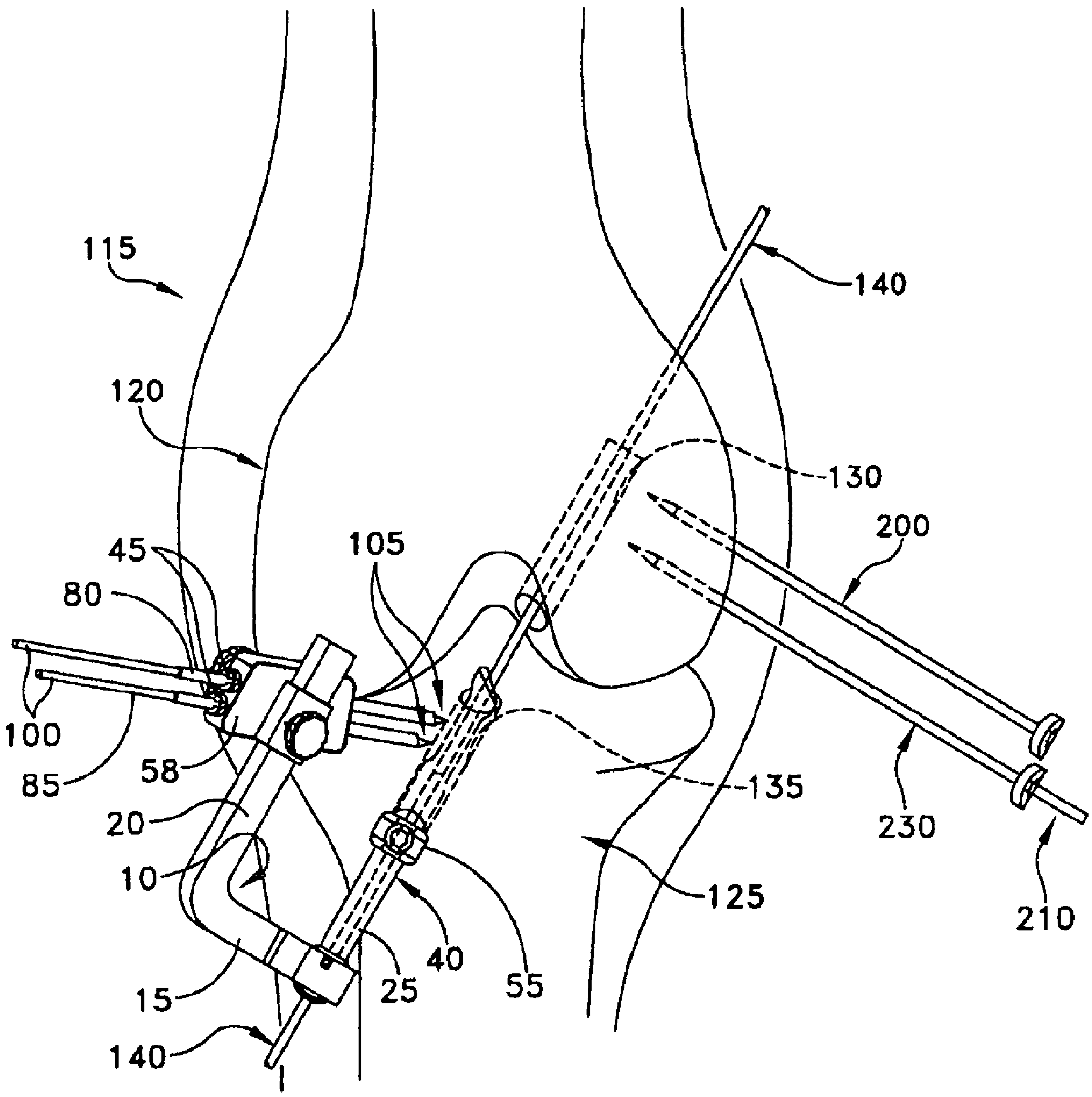
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FIG. 24

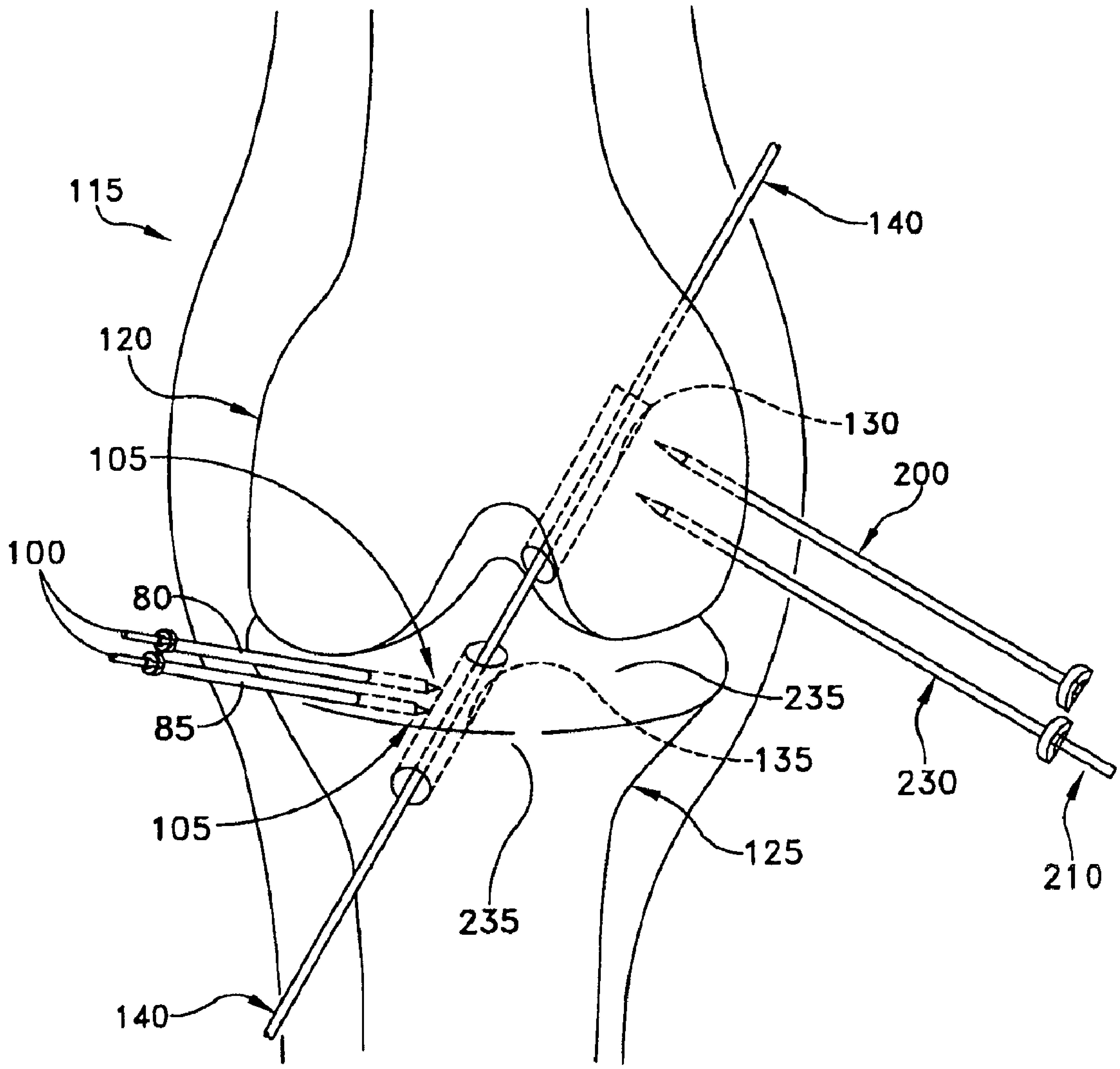

FIG. 25

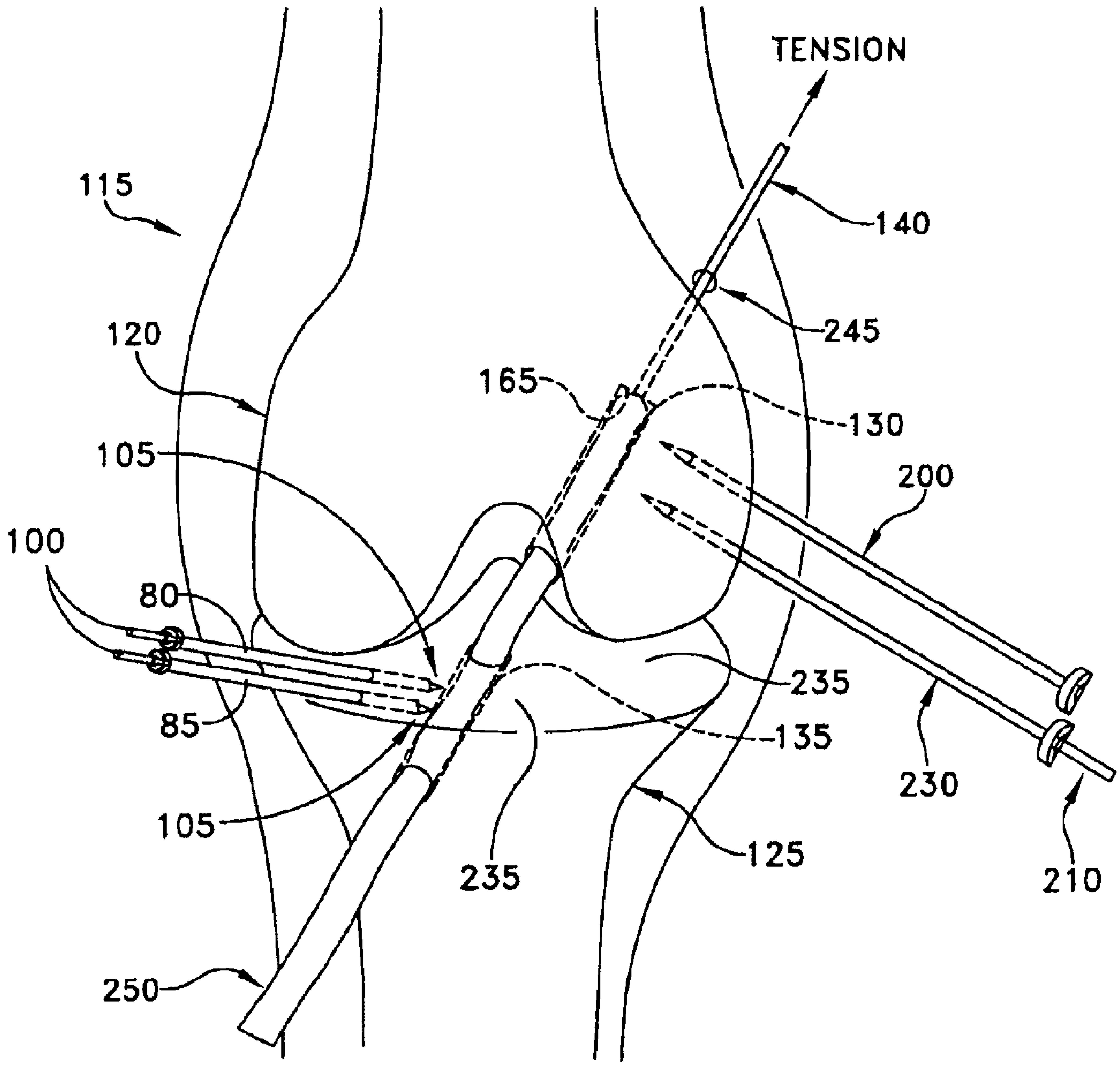
TENSION
115
140
245
120
165
130
105
200
100
80
235
85
135
230
105
235
125
210
250

FIG. 26

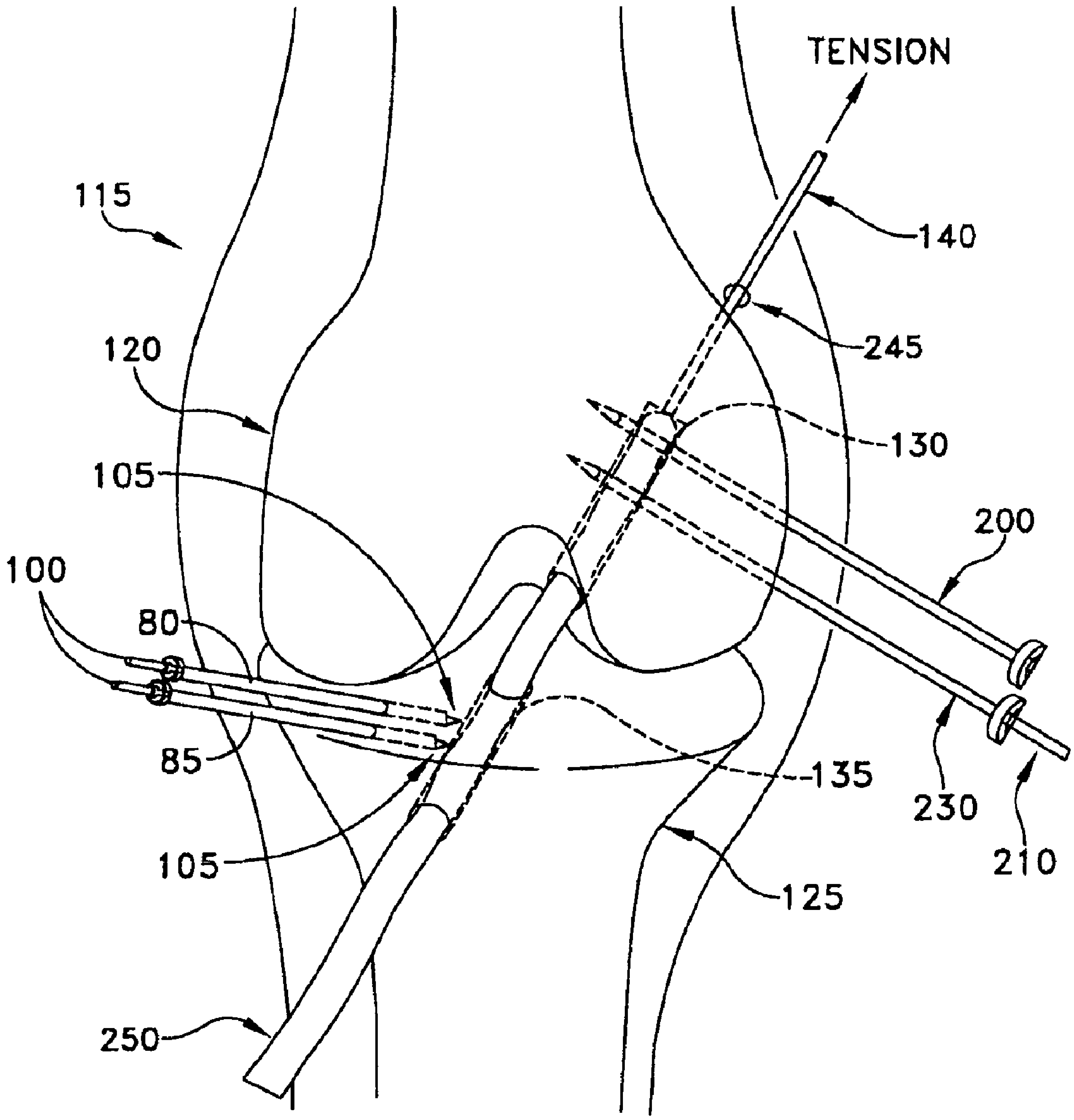
TENSION
115
140
245
120
130
105
200
100
80
85
135
230
210
105
125
250

FIG. 27

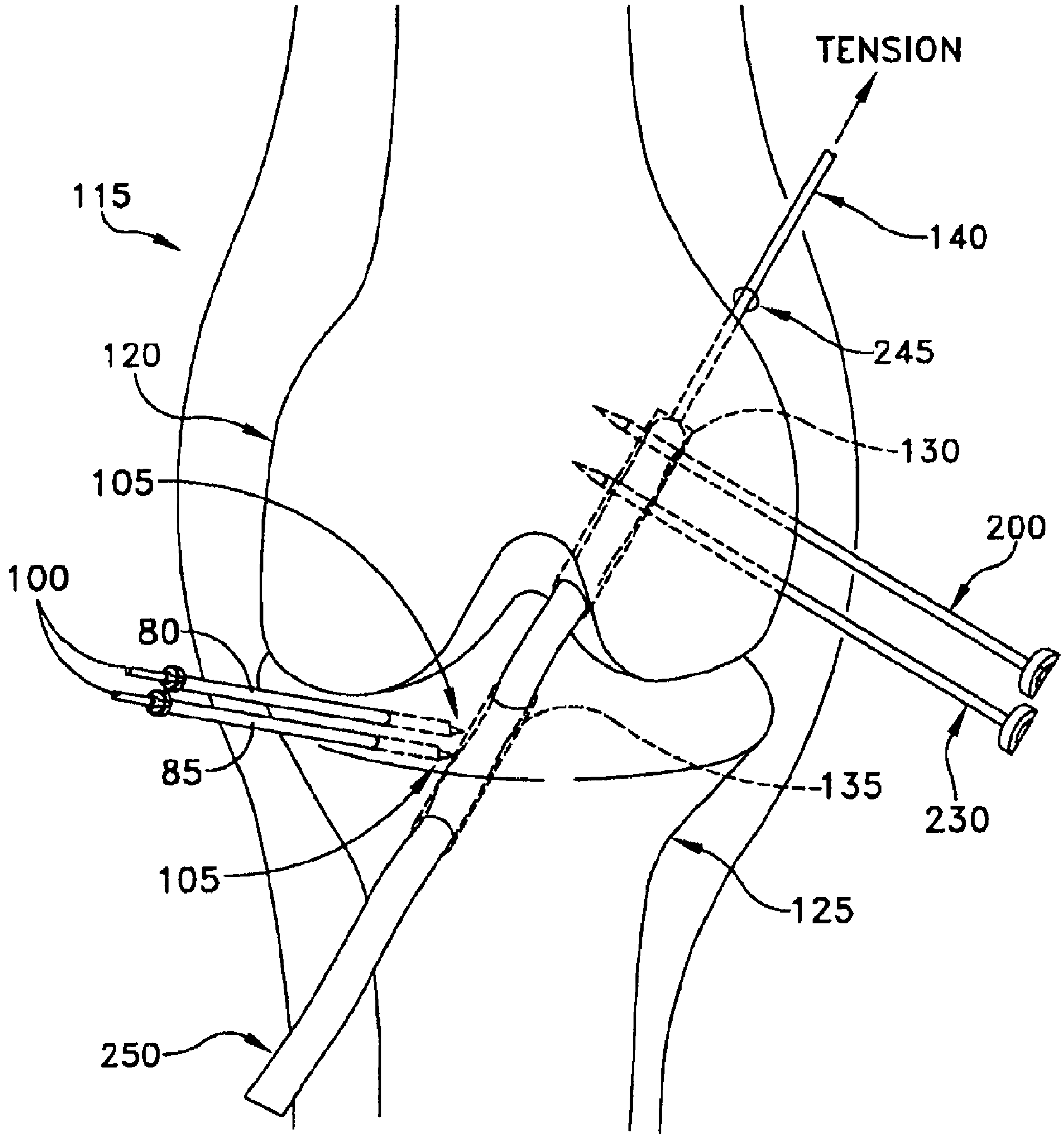
TENSION
115
140
245
120
130
105
200
100
80
85
135
230
105
125
250

FIG. 28

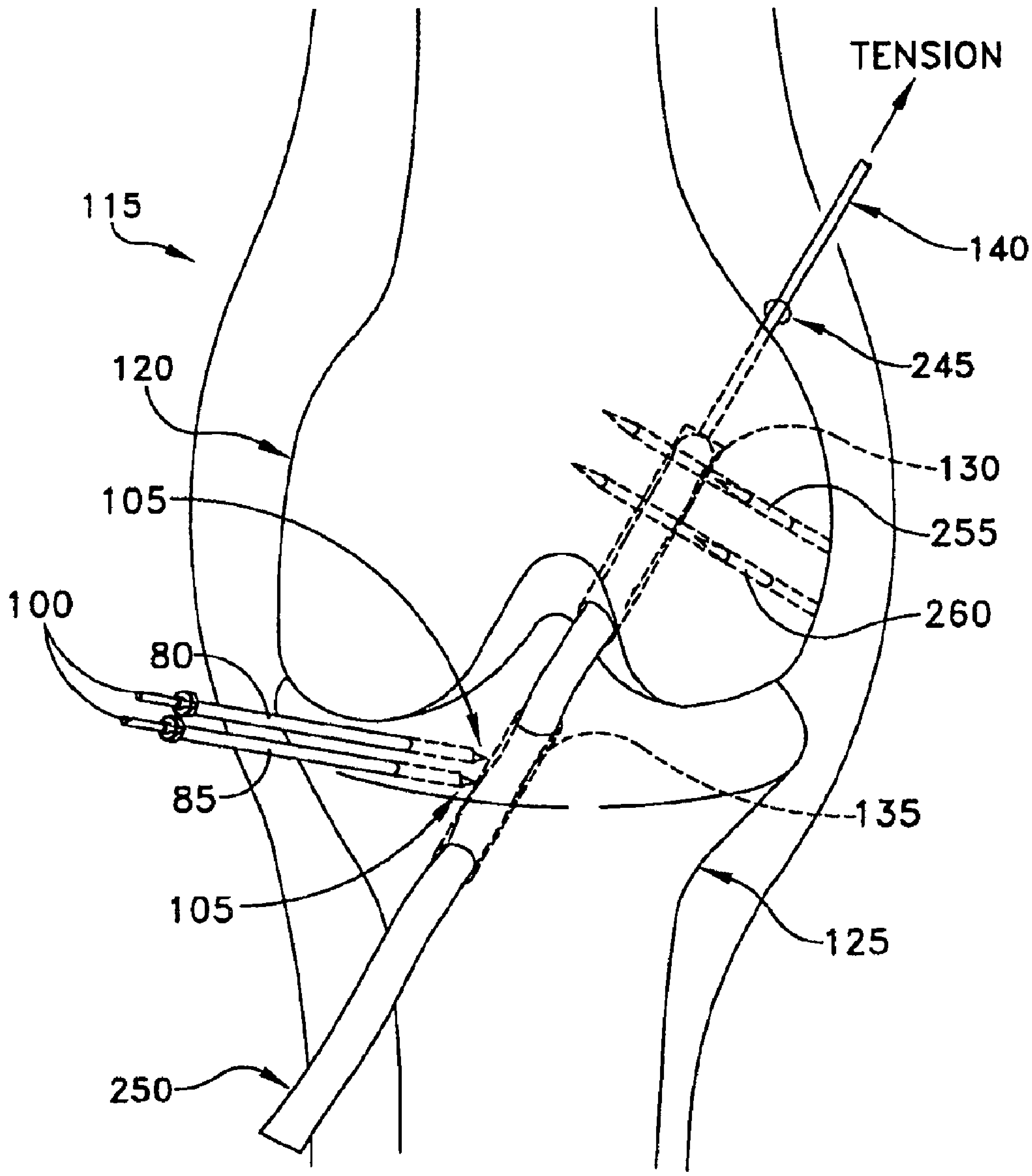
TENSION
115
140
245
120
130
105
255
100
260
80
85
135
105
125
250

FIG. 29

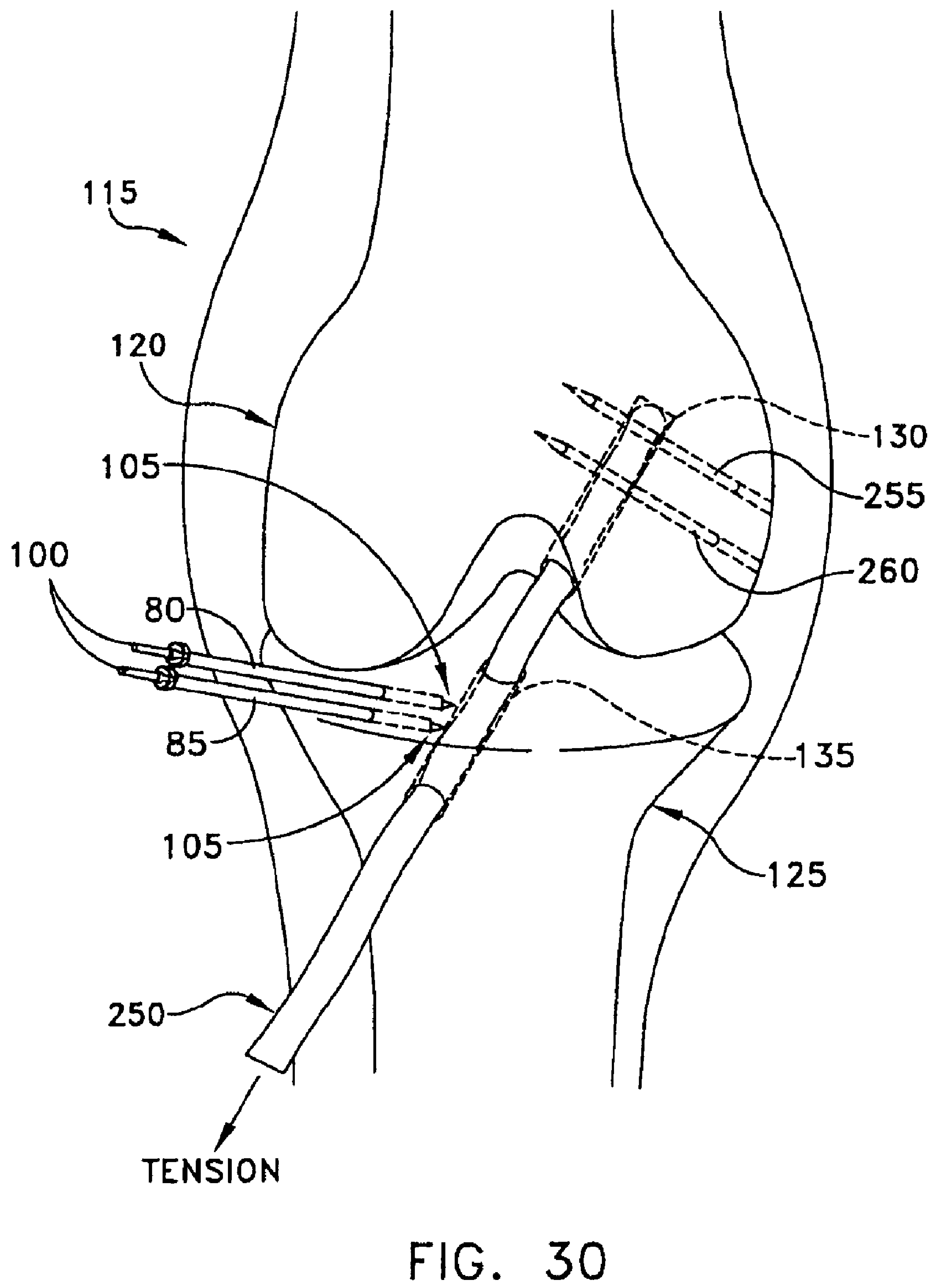

FIG. 30

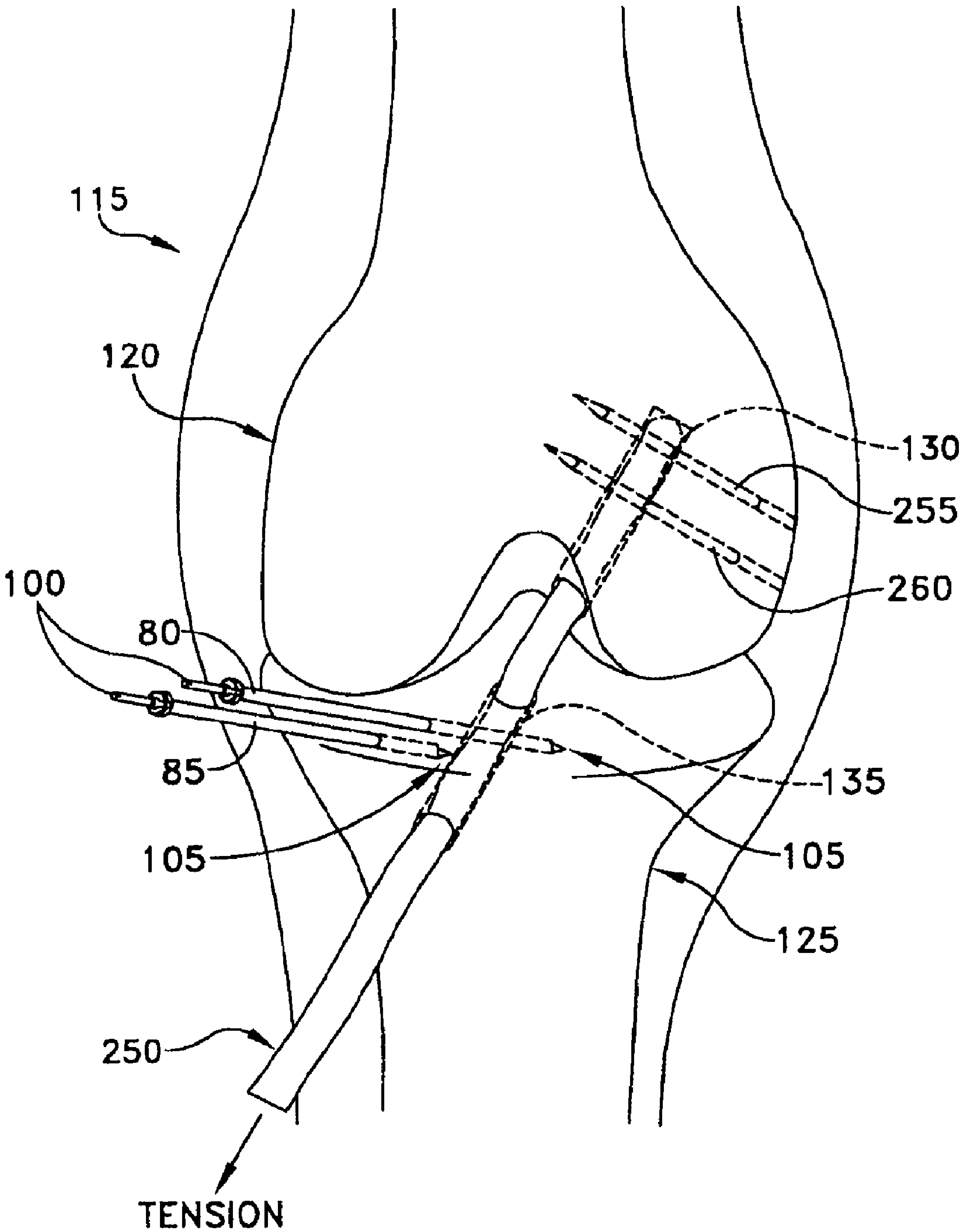

FIG. 31

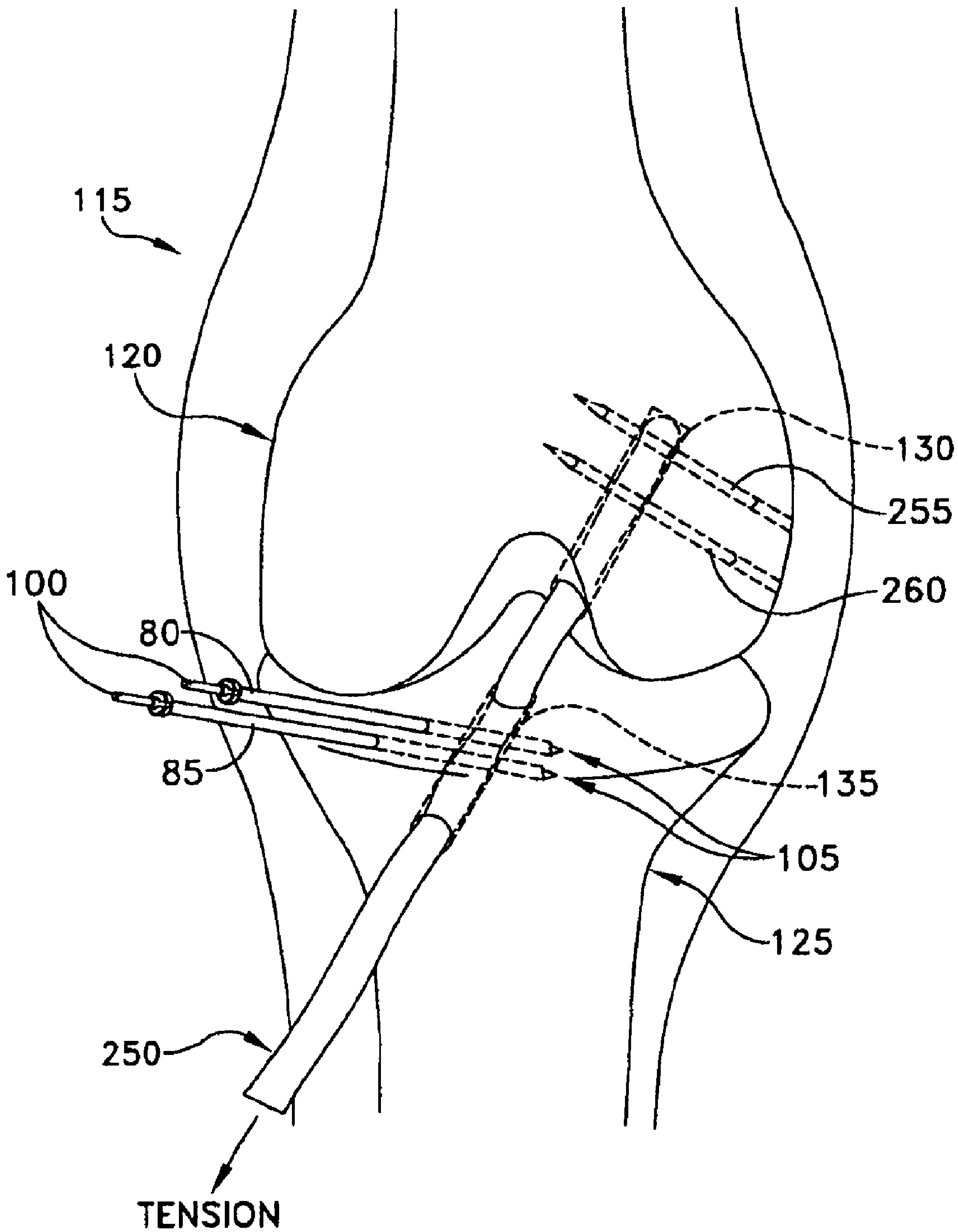

FIG. 32

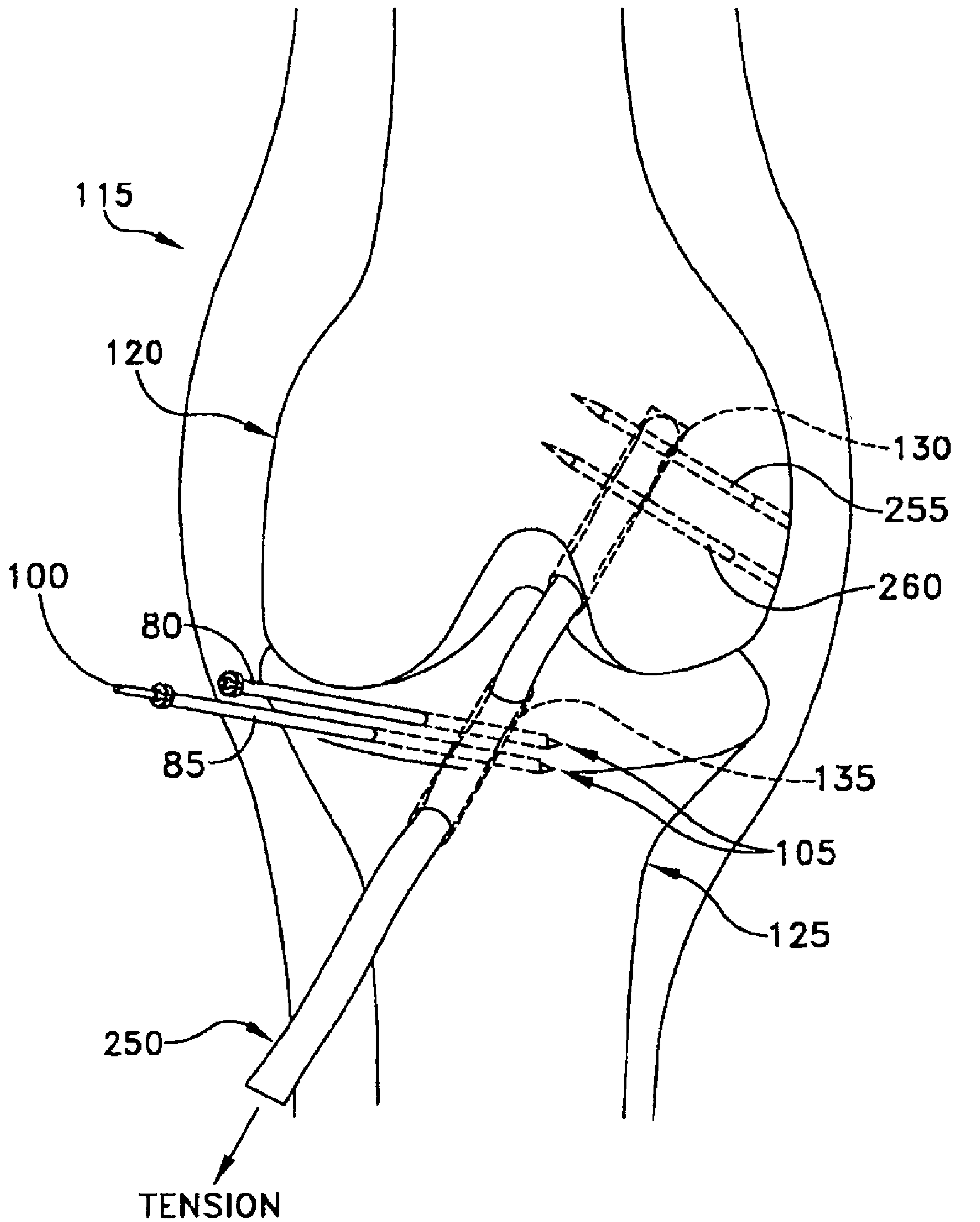

FIG. 33

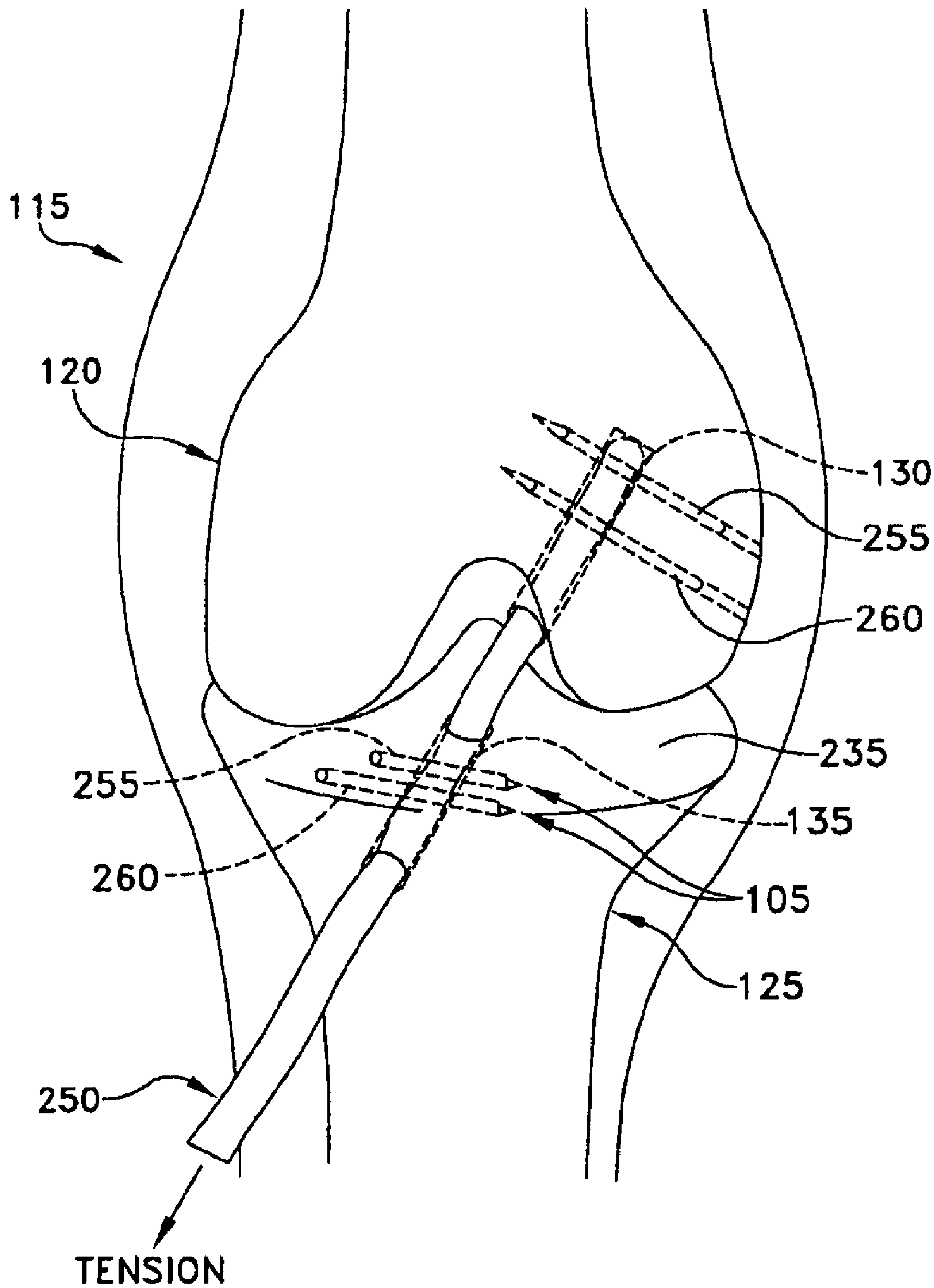

FIG. 34

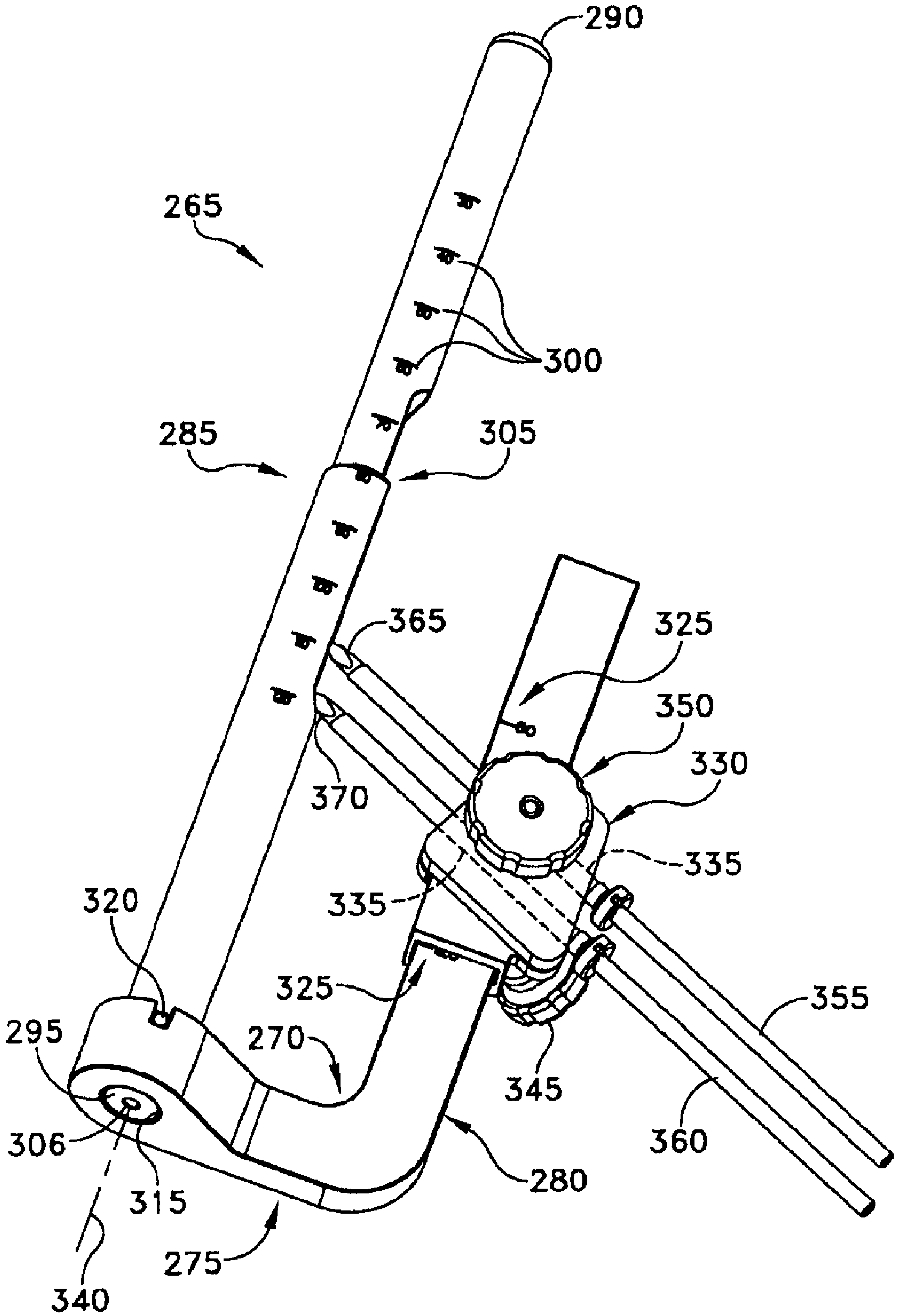
290
265
300
285
305
365
325
350
330
370
335
335
320
325
295
270
345
355
306
360
315
280
275
340

FIG. 35

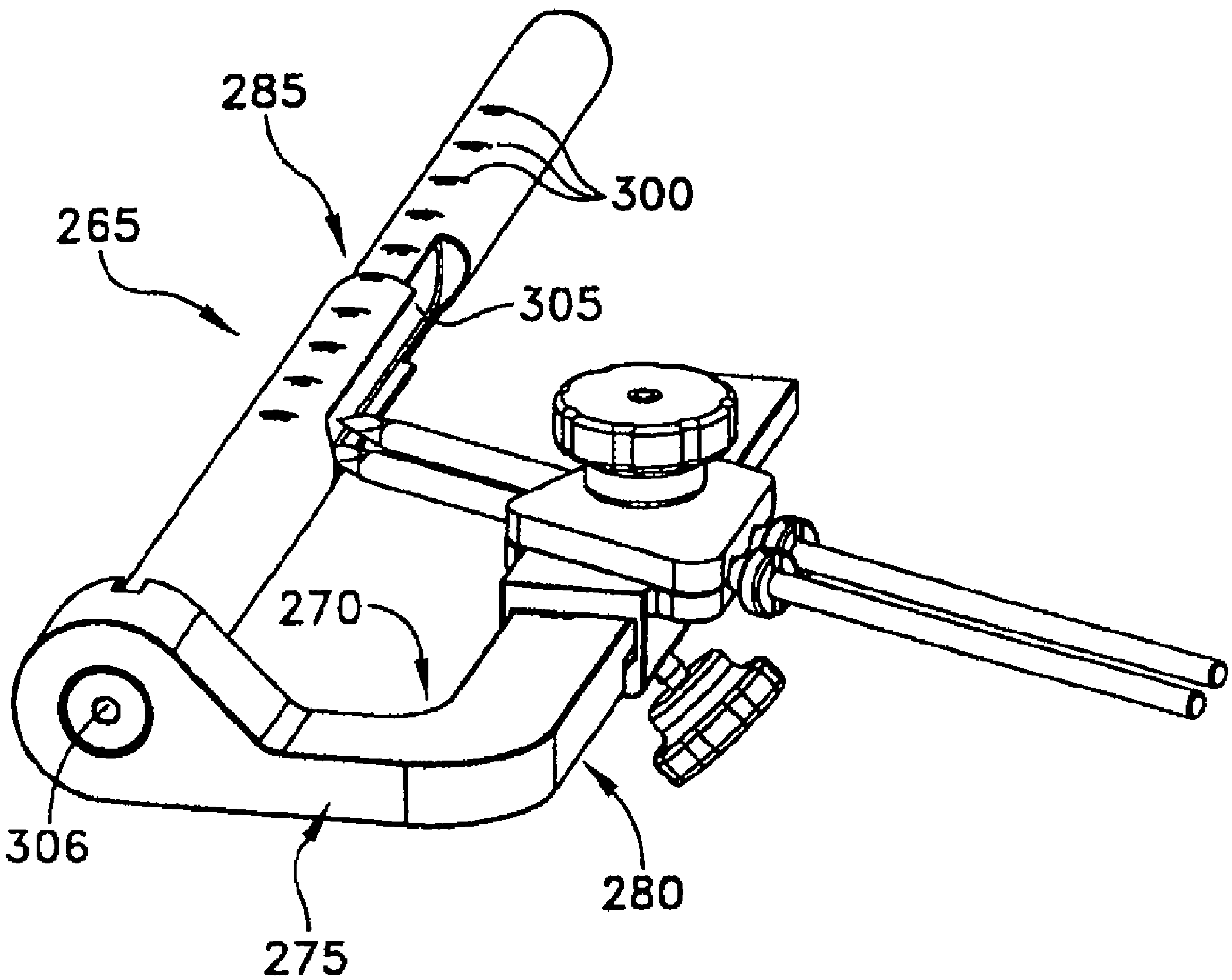

FIG. 36

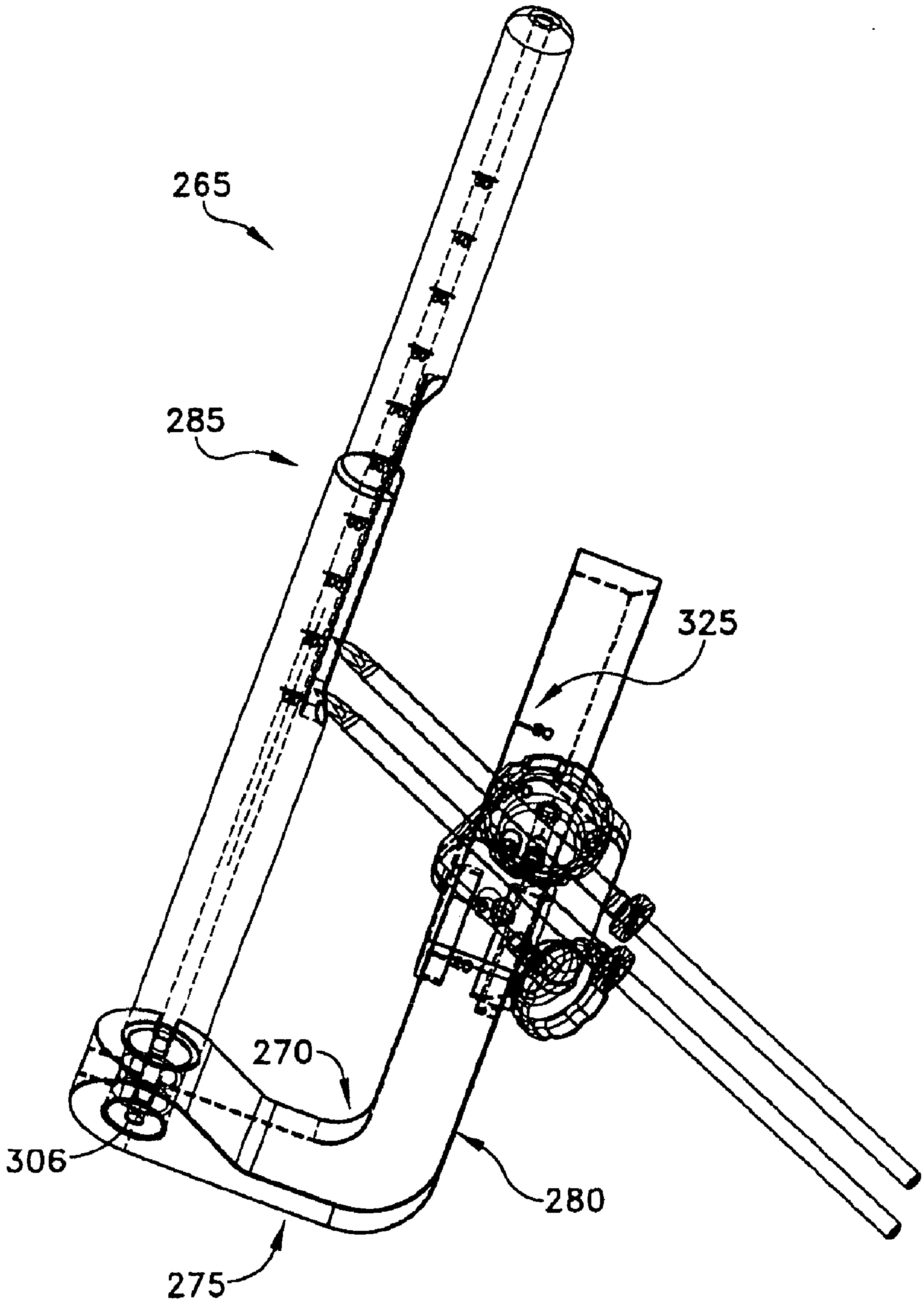

FIG. 37

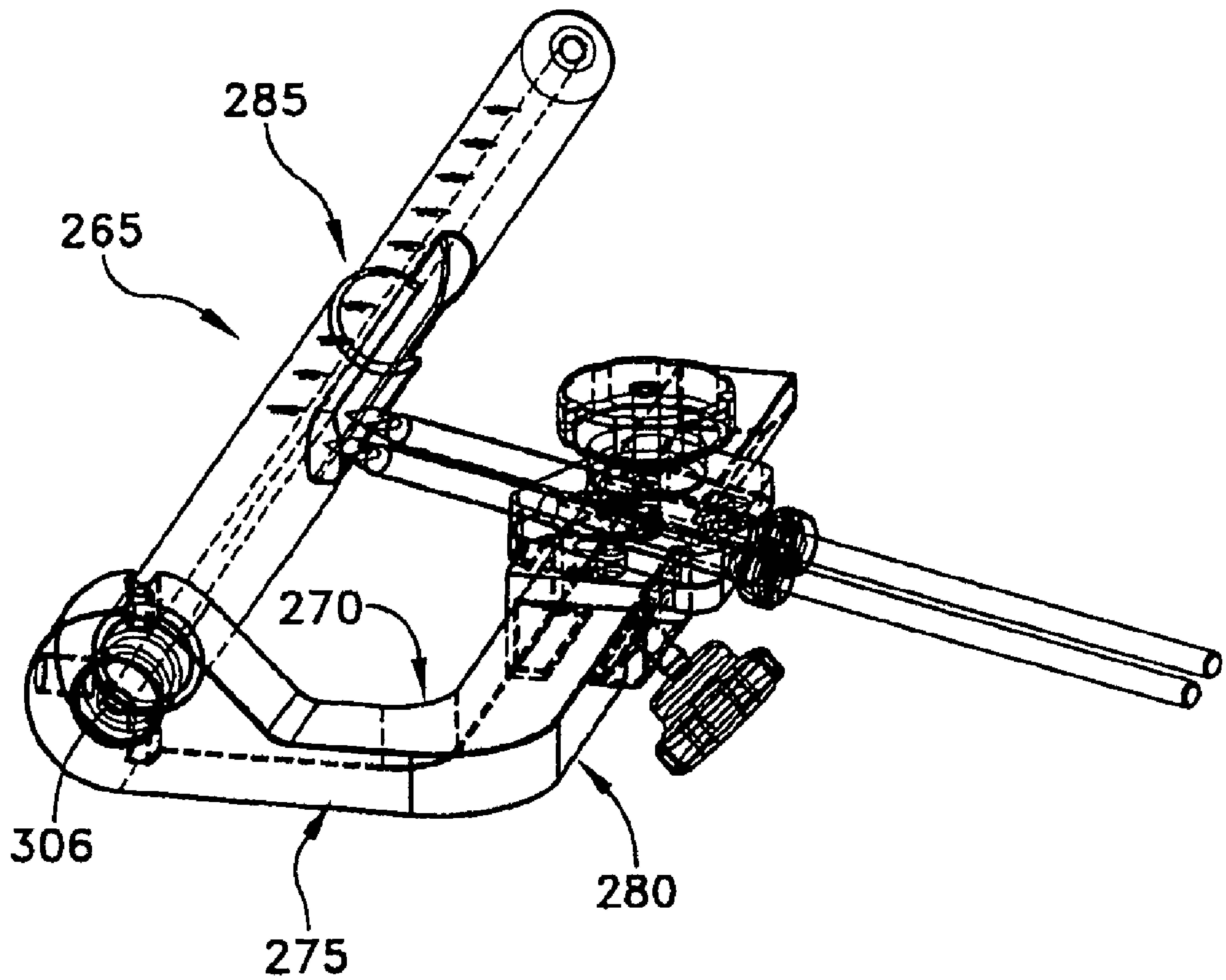

FIG. 38

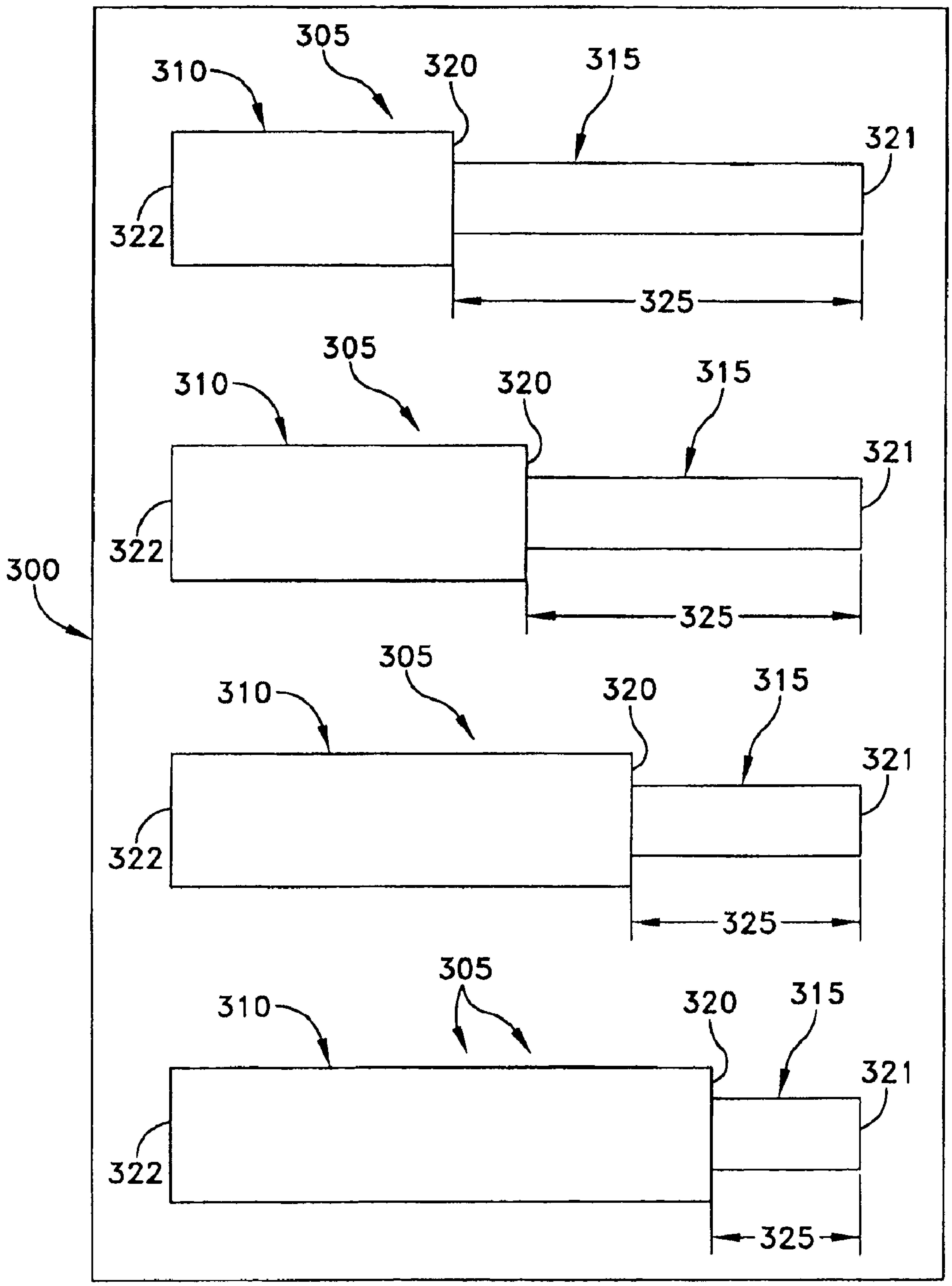
305
310
320
315
321
322
325
305
310
320
315
321
322
300
325
305
310
320
315
321
322
325
305
310
320
315
321
322
325

FIG. 39

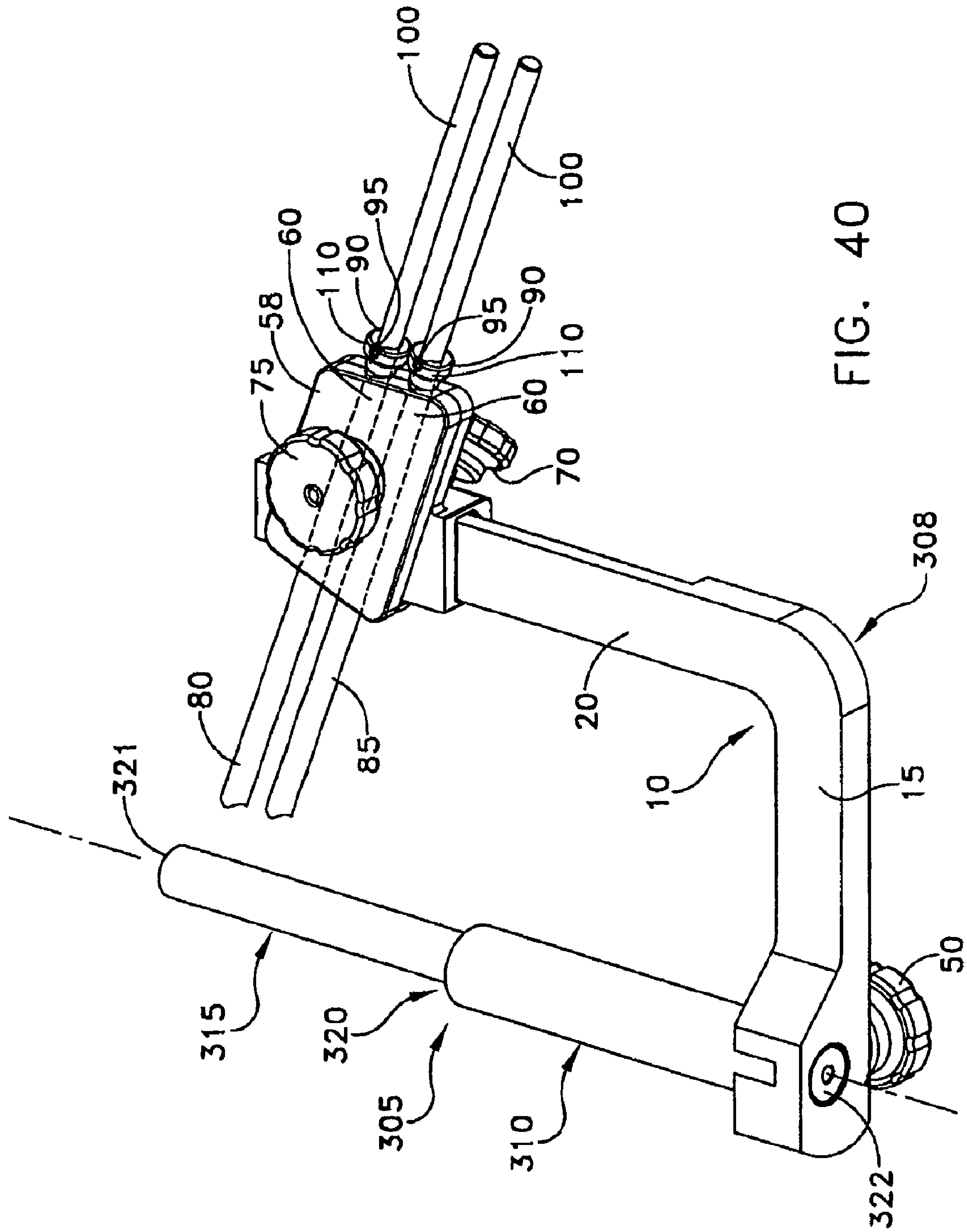
100
100
95
90
110
60
58
75
95
90
110
60
70
308
20
80
85
10
15
321
315
320
305
310
50
322

FIG. 40

METHOD AND APPARATUS FOR FIXING A GRAFT IN A BONE TUNNEL

REFERENCE TO PENDING PRIOR PATENT APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 11/088,250, filed Mar. 23, 2005 and entitled "METHOD AND APPARATUS FOR FIXING A GRAFT IN A BONE TUNNEL," which is a continuation of U.S. patent application Ser. No. 10/364,786 filed Feb. 11, 2003 and entitled "METHOD AND APPARATUS FOR FIXING A GRAFT IN A BONE TUNNEL," which is a continuation of U.S. patent application Ser. No. 09/865,274 filed May 25, 2001 and entitled "METHOD AND APPARATUS FOR FIXING A GRAFT IN A BONE TUNNEL," which claims benefit of pending prior U.S. Provisional Patent Application Ser. No. 60/275,431, filed Mar. 13, 2001 by Gregory Whittaker for "METHOD AND APPARATUS FOR FIXING A GRAFT IN A TIBIAL TUNNEL," each of which are hereby incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

This invention relates to surgical methods and apparatus in general, and more particularly to methods and apparatus for fixing a graft in a bone tunnel.

BACKGROUND OF THE INVENTION

The complete or partial detachment of ligaments, tendons and/or other soft tissues from their associated bones within the body are relatively commonplace injuries. Tissue detachment may occur as the result of an accident such as a fall, overexertion during a work-related activity, during the course of an athletic event, or in any one of many other situations and/or activities. Such injuries are generally the result of excess stress being placed on the tissues.

In the case of a partial detachment, commonly referred to under the general term "sprain", the injury frequently heals itself, if given sufficient time and if care is taken not to expose the injury to undue stress during the healing process. If, however, the ligament or tendon is completely detached from its associated bone or bones, or if it is severed as the result of a traumatic injury, partial or permanent disability may result. Fortunately, a number of surgical procedures exist for re-attaching such detached tissues and/or completely replacing severely damaged tissues.

One such procedure involves the re-attachment of the detached tissue using "traditional" attachment devices such as staples, sutures and/or cancellous bone screws. Such traditional attachment devices have also been used to attach tendon or ligament grafts (often formed from autogenous tissue harvested from elsewhere in the body) to the desired bone or bones.

Another procedure is described in U.S. Pat. No. 4,950,270, issued Aug. 21, 1990 to Jerald A. Bowman et al. In this procedure, a damaged anterior cruciate ligament ("ACL") in a human knee is replaced by first forming bone tunnels through the tibia and femur at the points of normal attachment of the anterior cruciate ligament. Next, a graft ligament, with a bone block on one of its ends, is sized so as to fit within the bone tunnels. Suture is then attached to the bone block, and the suture is thereafter passed through the tibial tunnel and then the femoral tunnel. The bone block is then drawn up through the tibial tunnel and up into the femoral tunnel using the suture. As this is done, the graft ligament extends back out the femoral tunnel, across the interior of the knee joint, and then out through the tibial tunnel. The free end of the graft ligament resides outside the tibia, at the anterior side of the tibia. Next, a bone screw is inserted between the bone block and the wall of femoral bone tunnel so as to securely lock the bone block in position by a tight interference fit. Finally, the free end of the graft ligament is securely attached to the tibia.

In U.S. Pat. No. 5,147,362, issued Sep. 15, 1992 to E. Marlowe Goble, there is disclosed a procedure wherein aligned femoral and tibial tunnels are formed in a human knee. A bone block, with a graft ligament attached thereto, is passed through the tibial and femoral tunnels to a blind end of the femoral tunnel, where the block is fixed in place by an anchor. The graft ligament extends out the tibial tunnel, and the proximal end thereof is attached to the tibial cortex by staples or the like. Alternatively, the proximal end of the ligament may be fixed in the tibial tunnel by an anchor or by an interference screw.

Various types of ligament and/or suture anchors, and anchors for attaching other objects to bone, are also well known in the art. A number of these devices are described in detail in U.S. Pat. Nos. 4,898,156; 4,899,743; 4,968,315; 5,356,413; and 5,372,599.

One known method for anchoring bone blocks in bone tunnels is through "cross-pinning", in which a pin, screw or rod is driven into the bone, transversely to the bone tunnel, so as to intersect the bone block and thereby "cross-pin" the bone block in the bone tunnel.

In this respect it should be appreciated that the cross-pin (i.e., the aforementioned pin, screw or rod) is generally placed in a pre-drilled transverse passageway. In order to provide for proper cross-pinning of the bone block in the bone tunnel, a drill guide is generally used. The drill guide serves to ensure that the transverse passageway is positioned in the bone so that the transverse passageway intersects the appropriate tunnel section and hence the bone block. Drill guides for use in effecting such transverse drilling are shown in U.S. Pat. Nos. 4,901,711; 4,985,032; 5,152,764; 5,350,380; and 5,431,651.

Other patents in which cross-pinning is discussed include U.S. Pat. Nos. 3,973,277; 5,004,474; 5,067,962; 5,266,075; 5,356,435; 5,376,119; 5,393,302; and 5,397,356.

Cross-pinning methods and apparatus currently exist for fixing a graft ligament in a femoral bone tunnel. However, the femoral cross-pinning methods and apparatus that are presently known in the art do not address the use of a cross-pin in a tibial bone tunnel, which involves a different set of considerations. Among these considerations are anatomical geometries, bone configurations, bone quality, etc.

Accordingly, there exists a need for a method and apparatus for positioning at least one cross-pin so as to fix a graft in a tibial bone tunnel.

There also exists a need for a method and apparatus for positioning at least one cross-pin across a tibial tunnel such that, upon completion of the procedure, the cross-pin is located in the cortical portion of the tibia, adjacent to the tibial plateau.

SUMMARY OF THE INVENTION

One object of the present invention is, therefore, to provide a novel method and apparatus for positioning at least one cross-pin so as to fix a graft in a tibial bone tunnel.

Another object of the present invention is to provide a novel method and apparatus for positioning at least one cross-pin across a tibial tunnel such that, upon completion of the procedure, the cross-pin is located in the tibia and, more preferably, in the cortical portion of the tibia, adjacent to the tibial plateau.

These and other objects of the present invention are addressed by the provision and use of a novel method and apparatus for fixing a graft in a bone tunnel.

In accordance with a feature of the present invention, there is provided apparatus for positioning at least one cross-pin in a bone through a bone tunnel, the apparatus comprising: a bone tunnel guide rod having a proximal end and a distal end; a movable element slidably positioned about the bone tunnel guide rod, wherein said movable element is lockable into a position to selectively adjust the length of said guide rod between said distal end and said movable element; a frame member having a base portion and an arm portion, the base portion attachable to the proximal end of the bone tunnel guide rod; a drill guide member attachable to the arm portion of the frame member; and drilling means for drilling at least one cross-pin hole in the bone and across the bone tunnel, with the drilling means being supported in position by the drill guide member, the drill guide member being in attachment with the frame member, the frame member being in attachment with the bone tunnel guide rod, and the bone tunnel guide rod being inserted into the bone tunnel, and the apparatus being held against the bone, with the movable element limiting further insertion into the bone tunnel.

In accordance with a further feature of the present invention, there is provided a method for fixing a ligament in a bone tunnel, the method comprising the steps of: forming a bone tunnel in a bone, the bone tunnel comprising a first open end and a second open end, with a portion between the first open end and the second open end having a diameter sized to receive the ligament; inserting a guide rod into the bone tunnel, the guide rod having a proximal end and a distal end; positioning the distal end of the guide rod adjacent to the second open end of the bone tunnel; positioning a movable element on the guide rod against the bone at the first open end of the bone tunnel; drilling at least one cross-pin hole transversely through the bone and across the bone tunnel, using drilling means for drilling the cross-pin hole, the drilling means being supported in position by a drill guide member, with that drill guide member being in attachment with a frame member, the frame member being In attachment with the bone tunnel guide rod, the bone tunnel guide rod being inserted into the bone tunnel, and with the movable element limiting further insertion of the bone tunnel guide rod into the bone tunnel; and inserting at least one cross-pin through at least one cross-pin hole.

In accordance with a further feature of the present invention, there is provided an apparatus for positioning at least one cross-pin in a bone through a bone tunnel, the apparatus comprising: a bone tunnel guide rod having a proximal end and a distal end, with the bone tunnel guide rod having a gradiated index between the proximal end and the distal end, wherein the gradiated index is read at a given position in the bone tunnel in relation to an intended position of at least one cross-pin hole; a frame member having a base portion and an arm portion, the base portion attachable adjacent to the proximal end of the bone tunnel guide rod, and the arm portion of the frame member having a scale corresponding with the gradiated index of the bone tunnel guide rod; a drill guide member attachable to the arm portion of the frame member, the drill guide member being selectively adjustable relative to the scale of the frame member; and drilling means for drilling the at least one cross-pin hole in the bone through the bone tunnel, the drilling means being supported in position by the drill guide member, the drill guide member being in attachment with the frame member, and the frame member being in attachment with the bone tunnel guide rod, with the bone tunnel guide rod being inserted into the bone tunnel, with the distal end of apparatus being held against a terminal end of the bone tunnel, limiting further insertion into the bone tunnel.

In accordance with a further feature of the present invention, there is provided a method for fixing a ligament in a bone tunnel, the method comprising the steps of: forming a bone tunnel in a bone, the bone tunnel comprising a first portion and a second portion, the first portion having a first open end and a second open end, and the second portion having a third open end and a fourth terminal end, and a portion between the first open end and the fourth terminal end having a diameter sized to receive the ligament; inserting a bone tunnel guide rod into the bone tunnel, the bone tunnel guide rod having a proximal end and a distal end, and the bone tunnel guide rod having a gradiated index between the proximal end and the distal end; positioning the distal end of the guide rod against the fourth terminal end of the bone tunnel; determining the position of the gradiated index relative to the second open end of the bone tunnel; positioning a drill guide attached to a frame member, the frame member including a scale corresponding with the gradiated index of the bone tunnel guide rod, the drill guide being positioned relative to the scale in accordance with the gradiated index relative to the second open end of the bone tunnel; drilling at least one cross-pin hole transversely through the bone into the bone tunnel using drilling means for drilling the cross-pin hole, the drilling means supported in position by the drill guide member, the drill guide member being in attachment with the frame member, the frame member being in attachment with the bone tunnel guide rod, the bone tunnel guide rod being inserted into the bone tunnel, and the fourth terminal end of the bone tunnel limiting further insertion into the bone tunnel; and inserting at least one cross-pin through the cross-pin hole.

In accordance with a further feature of the present invention, there is provided an apparatus for positioning at least one cross-pin in a bone through a bone tunnel, the apparatus comprising: a kit of bone tunnel guide rods, each of the bone tunnel guide rods including a proximal end and a distal end, and each of the bone tunnel guide rods including insertion limiting means for limiting insertion into the bone tunnel, the insertion limiting means of each of the bone tunnel guide rods being located a given distance from its distal end, the kit including at least two bone tunnel guide rods, with the given distance of each of the bone tunnel guide rods being different from one another, and wherein selection from the kit is made by inserting at least one of the bone tunnel guide rods into the bone tunnel and selecting a bone tunnel guide rod that has its distal end aligned with a bone surface when said insertion limiting means is in engagement with another bone surface; a frame member having a base portion and an arm portion, the base portion attachable adjacent to the proximal end of the selected bone tunnel guide rod; a drill guide member attached to the arm portion of the frame member; drilling means for drilling the at least one cross-pin hole in the bone through the bone tunnel, the drilling means being supported in position by the drill guide member, the drill guide member being in attachment with the frame member, and the frame member being in attachment with the selected bone tunnel guide rod, with the selected bone tunnel guide rod being inserted into the bone tunnel, and with the insertion limiting means preventing further insertion into the bone tunnel.

In accordance with a further feature of the present invention, there is provided a method for fixing a ligament in a bone tunnel, the method comprising the steps of: forming a bone tunnel in a bone, the bone tunnel comprising a first open end and a second open end, with a portion between the first open end and the second open end having a diameter sized to receive the ligament; inserting at least one guide rod from a kit of bone tunnel guide rods into the bone tunnel, each of the bone tunnel guide rods including a proximal end and a distal end, and each of the bone tunnel guide rods including insertion limiting means for limiting insertion into the bone tunnel, the insertion limiting means of each of the bone tunnel guide rods being located a given distance from its distal end, the kit including at least two bone tunnel guide rods, with the given distance of each of the bone tunnel guide rods being different from one another; inserting at least one of the bone tunnel guide rods into the bone tunnel and selecting a bone tunnel guide rod that has its distal end aligned with the second end of the bone tunnel when the insertion limiting means is in engagement with the bone adjacent the first end of the bone tunnel; drilling at least one cross-pin hole transversely through the bone and across the bone tunnel, using drilling means for drilling the cross-pin hole, the drilling means being supported in position by a drill guide member, with the drill guide member being in attachment with a frame member, the frame member being in attachment with the selected bone tunnel guide rod, the selected bone tunnel guide rod being inserted into the bone tunnel, and with the insertion limiting means limiting further insertion of the bone tunnel guide rod into the bone tunnel; and inserting at least one cross-pin through said at least one cross-pin hole.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and features of the present invention will be more fully discussed in, or rendered obvious by, the following detailed description of the preferred embodiments of the invention, which is to be considered together with the accompanying drawings wherein like numbers refer to like parts, and further wherein:

FIG. **1-13** are various views of one form of a cross-pin guide assembly for use in cross-pinning a graft in a tibial tunnel, illustrative of one preferred embodiment of the present invention;

FIG. **14** is a diagrammatical view of a human knee joint and illustrative of a step in a method in which the cross-pin guide assembly of FIGS. **1-13** is used;

FIGS. **15-34** are diagrammatical views illustrating a ligament reconstruction procedure in which the cross-pin guide of FIGS. **1-13** is used;

FIGS. **35-38** are various views of another form of a cross-pin guide assembly for use in cross-pinning a graft in a tibial tunnel, illustrative of another preferred embodiment of the present invention;

FIG. **39** is a schematic view of a kit of bone tunnel guide rods for use with a third embodiment of the present invention; and

FIG. **40** is a schematic view showing one of the bone tunnel guide rods of FIG. **39** with an associated cross-pin guide assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Looking first at FIGS. **1-10**, there is shown a cross-pin guide assembly **5** for placement of at least one cross-pin (not shown in FIGS. **1-10**) in a bone tunnel, such as the tibial tunnel of a knee joint. Cross-pin guide assembly **5** comprises an L-shaped member **10** having a base portion **15** and an arm portion **20**. The arm portion **20** extends transversely to, and preferably is normal to, base portion **15**.

Cross-pin guide assembly **5** further comprises a bone tunnel guide rod **25** which, adjacent to a first end **30** thereof, forms a diametrical, longitudinally-elongated passageway **35**, and which, at a second end **40** thereof, is releasably connectable to base portion **15** of L-shaped member **10**. In a preferred embodiment, bone tunnel guide rod **25** is cannulated along its axis **65** (see FIGS. **1-10**) for placement on a guidewire (not shown in FIGS. **1-10**). Bone tunnel guide rod **25** may be retained in a bore **45** formed in base portion **15** by a set screw **50**. In an alternative embodiment, bone tunnel guide rod **25** may be fixedly connected to base portion **15**.

Still looking at FIGS. **1-10**, a movable element **55** is positioned on bone tunnel guide rod **25** between first end **30** and second end **40**. Movable element **55** may be moved about on guide rod **25** so that the distance of movable element **55** from first end **30** may be selectively adjusted. Movable element **55** may also be secured to guide rod **25** at any of these longitudinal positions. In one preferred form of the invention, movable element **55** is movably secured to guide rod **25** using a ratchet system such as that shown in FIGS. **1-10**.

The present invention may be practiced with cross-pins of any type, and is independent of the type of cross-pins used in a surgical procedure. Preferably, cross-pins of an absorbable nature are used in a given surgical procedure. Accordingly, the ACL reconstruction will hereinafter be discussed in the context of using absorbable cross-pins, and in the context of using preferred apparatus for deploying such absorbable cross-pins.

More particularly, in a preferred embodiment using absorbable cross-pins **255**, **260** (FIG. **34**), a trocar sleeve guide member **58** (FIGS. **1-10**) is removably connectable to arm portion **20** of L-shaped member **10**. Trocar sleeve guide member **58** is provided with bores **60** extending therethrough. Bores **60** intersect the longitudinal axis **65** of the bone tunnel guide rod **25**. As such, at least one cross-pin is ultimately positioned in the tibia so as to pass through the tibial tunnel. More preferably, bores **60** are configured to intersect the longitudinal axis **65** of bone tunnel guide rod **25** just below the patient's tibial plateau. In this way, the at least one cross-pin will be deployed in the cortical portion of the tibia, adjacent to the tibial plateau, and at the region of greatest bone strength. A set screw **70** may be used to releasably retain trocar sleeve guide member **58** in position on arm portion **20**. Alternatively, or in addition, arm portion **20** may be provided with stop means (not shown) for limiting movement of the trocar sleeve guide member **58** along arm portion **20**. Trocar sleeve guide member **58** is preferably formed in two halves releasably held together by a set screw **75**, whereby trocar sleeve guide member **58** can be detached from first and second trocar sleeves **80**, **85** passing through bores **60**, as will hereinafter be discussed.

First and second trocar sleeves **80**, **85** (FIGS. **1-10** and **11-13**) are slidably received by bores **60** (FIG. **1**) such that sleeves **80**, **85** are axially and rotatably movable in bores **60**. Trocar sleeves **80**, **85** are each provided with a collar portion **90** having a diagonally-extending slot **95** formed therein. Cross-pin guide assembly **5** also preferably includes one or more trocars **100** (FIGS. **1-10** and **11-13**) for disposition in sleeves **80**, **85**. Each trocar **100** is provided with a sharp end **105** for penetration of bone. A transversely-extending pin **110** is provided near, but spaced from, the opposite end of trocar **100**. Pin **110** is fixed in place and is received by the slot **95** of trocar sleeves **80**, **85** such that axial (in a distal direction) and rotational movement of trocar **100** causes similar movement of sleeves **80**, **85**.

First and second absorbable rods **255**, **260** (see FIG. **34**), or rods of other types of known materials, are slidable through sleeves **80**, **85**, as will be further described hereinbelow.

In another preferred embodiment, guide member **58** is configured for the direct placement of cross-pins, without the use of trocar sleeves **80**, **85** and trocars **100**. In this case, the cross-pins are inserted through, and guided by, each of bores **60** in guide member **58**.

Referring now to FIG. **14**, there is shown a human knee joint **115** including a femur **120** and a tibia **125**. An appropriate femoral tunnel **130** and an appropriate tibial tunnel **135** are provided, as by means and methods well known in the art. A guidewire **140** extends through the tunnels **130**, **135** as shown.

Now looking at FIG. **15**, a femoral cross-pinning rack assembly **145**, or another similar system, is provided to position cross-pins **255**, **260** (FIG. **30**) across femoral tunnel **130**. Using rack assembly **145**, a cannulated sleeve **155** is loaded on guidewire **140**, passed through tibial tunnel **135** and up into femoral tunnel **130** until the cannulated sleeve's head portion **160** (FIG. **15**) engages in an annular shoulder **165** in femoral tunnel **130**. Guidewire **140** extends through a bore **170** (FIG. **15**) formed in a base portion **175** of L-shaped member **180**. The cannulated sleeve's head portion **160** is preferably sized so as to form a snug fit in femoral tunnel **130**. Cannulated sleeve **155** may be positioned in the bone tunnels **130**, **135** and then connected to L-shaped member **180** or, more preferably, cannulated sleeve **155** may be first connected to L-shaped member **180** and then positioned in femoral tunnel **130** and tibial tunnel **135**. Trocar sleeve guide member **185** (FIG. **15**), if not already positioned on an arm portion **190**, is then fixed to arm portion **190**, as by a set screw (not shown).

Now looking at FIG. **16**, first trocar sleeve **200** is then inserted in a bore **205** of guide member **185** (FIG. **16**), and trocar **210** is extended through sleeve **200** until pin **215** of trocar **210** is nestled in slot **220** of sleeve **200**, with the trocar's sharp end **225** extending beyond the distal end of sleeve **200**. Alternatively, trocar **210** may be mounted in first trocar sleeve **200** before the first trocar sleeve **200** is mounted in bore **205**. In any case, the combination of trocar sleeve **200** and trocar **210** is then drilled, as a unit, into femur **120** toward, but stopped short of, the enlarged head portion. **160** of cannulated sleeve **155** (FIG. **16**).

Trocar **210** may then be withdrawn from first trocar sleeve **200** and placed in a second trocar sleeve **230** (FIG. **17**). Alternatively, a second trocar **210** may be provided for second trocar sleeve **230**. In either case, the combination of trocar sleeve **230** and trocar **210** is then drilled, as a unit, into femur **120** toward, but again stopped short of, head portion **160** of cannulated sleeve **155** (FIG. **17**). The rack's L-shaped member **180** may then be removed from the surgical site (FIG. **18**). This may be accomplished by first loosening a set screw (not shown) to separate trocar sleeve guide member **185** into its two halves, whereby trocar sleeves **200**, **230** will be freed from guide member **185**, and then sliding cannulated sleeve **155** downward along guidewire **140** until the cannulated sleeve emerges from bone tunnels **130**, **135**. This procedure will leave trocar sleeves **200**, **230** lodged in femur **120** (FIG. **18**).

Referring now to FIG. **19**, the bone tunnel guide rod **25** (FIGS. **1-10**) is fed over guidewire **140** and up into tibial tunnel **135** until the guide rod's first end **30** is aligned with tibial plateau **235**. An arthroscope **240** may be used to determine when the guide rod's first end **30** is aligned with tibial plateau **235**.

Referring now to FIG. **20**, movable element **55** (FIGS. **1-10**) is then moved along guide rod **25** toward the guide rod's first end **30** and tibia **125**. When movable element **55** is positioned against tibia **125** (and the guide rod's first end **30** is positioned adjacent tibial plateau **235**), movable element **55** is locked in position such that guide rod **25** cannot travel further into tibial tunnel **135**. In this configuration, guide assembly **5** may be stabilized against tibia **125** by applying a distally-directed force to guide rod **25**, with movable element **55** maintaining the position of the guide rod relative to tibia **125**.

Now looking at FIG. **21**, bone tunnel guide rod **25** is shown connected to L-shaped member **10** and positioned in tibial tunnel **135**. In one embodiment, bone tunnel guide rod **25** may be first connected to L-shaped member **10** and then positioned in tibial tunnel **135**. Alternatively, in a preferred embodiment, bone tunnel guide rod **25** is first positioned in tibia tunnel **135** and then connected to L-shaped member **10**. In either case, movable element **55** properly locates bone tunnel guide rod **25** relative to tibia **125** so that the guide rod's first end **30** is aligned with tibial plateau **235**. Trocar sleeve guide member **58** (FIGS. **1-10**), if not already positioned on arm portion **20**, is then fixed to arm portion **20**, such as by set screw **50** (FIGS. **1-10**). Guide assembly **5** has a geometry such that when first end **30** of bone tunnel guide rod **25** is positioned in tibial tunnel **135**, and movable element **55** is in engagement with the front surface of tibia **125**, the cross-pins **255**, **260** (FIG. **34**) will be directed with a desired orientation within the tibial bone and, more preferably, through the strong cortical bone located just below the tibial plateau **235** (FIG. **34**).

Now referring to FIG. **22**, first trocar sleeve **80** is then inserted in bore **60** of guide member **58**, and trocar **100** is extended through sleeve **80**, with the trocar's sharp end **105** extending beyond the distal end of sleeve **80**. Alternatively, trocar **100** may be mounted in first trocar sleeve **80** before first trocar sleeve **80** is mounted in the guide member's bore **60**. In either case, the combination of trocar sleeve **80** and trocar **100** is then drilled, as a unit, into tibia **125** toward, but stopped short of, the guide rod's passage **35** (FIG. **22**).

Trocar **100** may then be withdrawn from first trocar sleeve **80** and placed in second trocar sleeve **85**. Alternatively a second trocar **100** may be provided for second trocar sleeve **85**. In either case, the combination of trocar sleeve **85** and trocar **100** is then drilled (FIG. **23**) as a unit into tibia **125** toward, but stopped short of, the guide rod (FIG. **24**).

The guide assembly's L-shaped member **10** may then be removed from the surgical site. This may be accomplished by first loosening set screw **75** (FIGS. **1-10**) so as to separate trocar sleeve guide member **58** into its two halves, whereby trocar sleeves **80**, **85** will be freed from guide member **58**, and then sliding bone tunnel guide rod **25** downward along guidewire **140** until the guide rod **25** emerges from tibial bone tunnel **135**. This procedure will leave trocar sleeves **80**, **85** lodged in tibia **125** (FIG. **25**).

Significantly, due to the geometry of guide assembly **5**, trocar sleeves **80**, **85** (and hence cross-pins **255**, **260**) will be directed into the strong cortical bone located just beneath tibial plateau **235**.

Guidewire **140** is then used to pull a suture **245**, which is attached to a craft ligament **250** (including, but not limited to, soft tissue grafts and bone block grafts) up through tibial tunnel **135** and into femoral tunnel **130**, until graft ligament **250** engages the annular shoulder **165** in femoral tunnel **130** (FIG. **26**). Guidewire **140** may be provided with an eyelet (not shown) adjacent to its proximal end so as to facilitate this procedure. Graft ligament **250** can then be held in this position by maintaining tension on the portion of suture **245** emerging from the top of femur **120**.

Trocar **210** may then be removed from second trocar sleeve **230**, placed in first trocar sleeve **200**, and then sleeve **200** and trocar **210** drilled through the distal end of graft ligament **250**, as shown in FIG. **27**. Trocar **210** may then be removed from sleeve **200**, placed in second sleeve **230**, and second sleeve **230** and trocar **210** drilled through the distal end of graft ligament **250**, as also shown in FIG. **27**. The trocar **210** (or trocars **210** if more than one trocar is used) may then be withdrawn from sleeves **200**, **230** (FIG. **28**). A first absorbable rod **255** (FIG. **29**) is then deployed, by sliding rod **255** through trocar sleeve **200**, into a position extending through ligament **250**. Sleeve **200** may then be withdrawn from ligament **250** and femur **120**, leaving first absorbable rod **255** in place in femur **120** and extending through ligament **250**. Similarly, second absorbable rod **260** may be slid into place through sleeve **230**. Sleeve **230** is then removed, leaving second absorbable rod **260**, along with first absorbable rod **255**, extending through ligament **250** so as to lock ligament **250** in place in femoral tunnel **130**, as shown in FIG. **29**.

Looking next at FIG. **30**, graft ligament **250** is then held in position by maintaining tension on the proximal portion of ligament **250** emerging from the bottom of tibia **125**.

Next, graft ligament **250** is attached to tibia **125**. More particularly, first trocar sleeve **80** and a trocar **100** are drilled through ligament **250**, as shown in FIG. **31**. Trocar **100** may then be removed from first sleeve **80**, placed in second sleeve **85**, and second sleeve **85** and trocar **100** drilled through ligament **250**, as shown in FIG. **32**. Alternatively, a second trocar **100** may be provided for use with second sleeve **85**. In either case, after trocar sleeves **80** and **85** have been set, the trocar **100** (or trocars **100**, if more than one trocar is used) may then be withdrawn from sleeves **80**, **85** (FIG. **33**). A first absorbable rod **255** is then inserted, by sliding rod **255** through trocar sleeve **80**, into a position extending through ligament **250**. Sleeve **80** may then be withdrawn from ligament **250** and tibia **125**, leaving first absorbable rod **255** in place in tibia **125** and extending through ligament **250**. Similarly, a second absorbable rod **260** is then slid into place through sleeve **85**. Sleeve **85** is then removed, leaving second absorbable rod **260**, along with first absorbable rod **255**, extending through ligament **250** so as to lock ligament **250** into place in tibial tunnel **135**, as shown in FIG. **34**.

Now referring to FIGS. **35-38**, there is shown a bone tunnel reference guide **265** for placement of at least one cross-pin (not shown in FIGS. **35-38**) in a bone tunnel such as the tibial tunnel of a knee joint. Bone tunnel reference guide **265** may be used in procedures to fix graft ligaments (including both soft tissue grafts and bone block grafts) in bone tunnels. Bone tunnel reference guide **265** comprises an L-shaped member **270** having a base portion **275** and an arm portion **280**. The arm portion **280** extends transversely to, and preferably is normal to, base portion **275**.

Bone tunnel reference guide **265** further comprises a bone tunnel guide rod **285** having a first end **290** and a second end **295**. Bone tunnel guide rod **285** includes a gradiated index **300** between first end **290** and second end **295**. Bone tunnel guide rod **285** includes a diametrically-extending, longitudinally-elongated passageway **305** intermediate its length and, at second end **295**, is connected to base portion **275** of L-shaped member **270**. In a preferred embodiment, bone tunnel guide rod **285** is cannulated at **306** (FIG. **35**) for placement on a guidewire (not shown in FIG. **35**). Bone tunnel guide rod **285** may be retained in a bore **315** formed in base portion **275** by a pin **320**.

Still looking at FIGS. **35-38**, a scale **325** is provided on arm portion **280** of L-shaped member **270**. Scale **325** is coordinated with gradiated index **300** on bone tunnel guide rod **285** as will hereinafter be discussed.

The present invent on may be practiced with cross-pins of any type, and is independent of the type of cross-pins used in a surgical procedure. Preferably, cross-pins of an absorbable nature are used in a given surgical procedure. Accordingly, the ACL reconstruction will hereinafter be discussed in the context of using absorbable pins, and in the context of using preferred apparatus for deploying such absorbable pins.

More particularly, in a preferred embodiment using absorbable cross-pins, a trocar sleeve guide member **330** is removably connectable to, and selectably adjustable along, scale **325** of arm portion **280** of L-shaped member **270**. Trocar sleeve guide member **330** is provided with bores **335** extending therethrough. Bores **335** extend through a longitudinal axis **340** of bone tunnel guide rod **285**. As such, at least one cross-pin is ultimately positioned in the tibia so as to pass through the tibial tunnel. More preferably, bores **335** are configured to intersect the longitudinal axis **340** of bone tunnel guide **285** just below the patient's tibial plateau. In this way, the at least one cross-pin will be deployed in the cortical portion of the tibia, adjacent to and just below the tibial plateau, and at the region of greatest bone strength. A set screw **345** may be used to releasably retain trocar sleeve guide member **330** in position along scale **325** of arm portion **280**. Trocar sleeve guide member **330** is preferably formed in two halves releasably held together by a set screw **350**, whereby trocar sleeve guide member **330** can be detached from first and second trocar sleeves **355**, **360** passing through bores **335**, as will hereinafter be discussed.

In another preferred embodiment, trocar sleeve guide member **330** is configured for direct placement of cross-pins, without the use of trocar sleeves **355**, **360**. In this case, cross-pins are inserted through, and guided by each of bores **335** in guide member **330**.

Bone tunnel reference guide **265** is preferably used as follows. First, femoral tunnel **130** and tibial tunnel **135** (FIG. **14**) are formed. Then the reference guide's guide rod **285** (FIGS. **35-38**) is passed up tibial tunnel **135** and femoral tunnel **130** until the distal end **290** of guide rod **285** is in engagement with the distal end **165** of femoral tunnel **130** (FIG. **14**). As this occurs, the reference guide's L-shaped member **270** will support trocar sleeve guide member **30** outboard of the patient's femur. Stabilization of the bone tunnel reference guide **265** is provided by applying a distally-directed force to guide rod **285**, which is in engagement with the distal end **165** of femoral tunnel **130**. This stabilization allows accurate placement of the cross-pins. Then an arthroscope is used to read the gradiated index **300** at the point at which guide rod **285** crosses the tibial plateau. Trocar sleeve guide member **330** is then set at a corresponding location along its own scale **325**. In this respect it will be appreciated that gradiated index **300** is coordinated with scale **325** so that the axes of bores **335** (FIG. **35**), and hence the cross-pins, will pass through the tibia at a desired position, such as through the tibia's cortical bone just below the tibial plateau.

Next, drill sleeves **355**, **360** are used to set trocars **365**, **370** into the tibia. Trocar sleeve guide member **330** is then separated into its two halves so as to free drill sleeves **355**, **360** from reference guide **265**, and the reference guide **265** is removed from the surgical site, e.g., by withdrawing it proximally off the guidewire. Then the graft ligament is pulled up into femoral tunnel **130** and tibial tunnel **135**, the distal end of the graft ligament is made fast in femoral tunnel **130**, and then drill sleeves **355**, **360** are used to set absorbable cross-pins through the proximal end of the graft ligament, whereby to cross-pin the ligament to the tibia.

Now looking at FIG. **39**, there is shown a kit **300** of bone tunnel guide rods **305** for use with a cross-pin guide assembly such as the cross-pin guide assembly **308** shown in FIG. **40**. In one preferred form of the invention, cross-pin guide assembly **308** is similar to the cross-pin guide assembly **5** shown in FIGS. **1-10**, except that bone tunnel guide rod **25** of cross-pin guide assembly **5** is replaced with one of the bone tunnel guide rods **305** shown in FIG. **39**.

Each of the bone tunnel guide rods **305** includes a proximal end **310** and a distal end **315**. As insertion limiting means **320**, for limiting insertion into a bone tunnel, is located between proximal end **310** and distal end **315**. Preferably insertion limiting means **320** comprises an annular shoulder formed intermediate the distal end **321** and the proximal end **322** of a given bone tunnel guide rod **305**.

Insertion limiting means **320** are located at a given distance **325** from the distal end **321** of bone tunnel guide rods **305**. Each kit **300** includes at least two bone tunnel guide rods, with the given distance **325** of each of the tunnel guide rods being different from one another. As such, selection is made from kit **300** by inserting at least one of the bone tunnel guide rods **305** into a bone tunnel and selecting the one of the bone tunnel guide rods **305** that has its distal end **321** aligned with the patient's tibial plateau when insertion limiting means **320** are in engagement with the front side of the patient's tibia. As a result of this construction, when that selected bone tunnel guide rod **305** is loaded in cross-pin guide assembly **308**, bores **60** (FIG. **40**), and hence the cross-pins, will be aimed at the thick cortical bone directly beneath the tibial plateau, whereby to enable secure and reliable tibial cross-pinning.

It is to be understood that the present invention is by no means limited to the specific applications thereof as herein disclosed and/or shown in the drawings. For example, for illustrative purposes, the inventive method and apparatus are described herein and illustrated with reference to the human knee joint. It is anticipated that the method and apparatus described herein will be particularly beneficial with respect to such operations. However, it will also be appreciated by those skilled in the art that the method and apparatus described herein will find utility with respect to mammals generally, and with respect to other bones as, for example, in shoulder joints or the like.

Furthermore, trocars **100** and **210** are disclosed herein as being in the form of a hard rod with a sharp tip for penetrating bone. Thus, for example, trocars **100** and **210** might comprise guidewires or K-wires with a pyramidal front point. Alternatively, however, the invention might also be practiced with trocars **100** and **210** comprising a twist drill, a spade drill and/or some other sort of drill.

Also it is contemplated that trocars **100** and/or **210** might be used with their associated guide member **58**, rack assembly **145**, reference guide **265**, guide assembly **308** and/or apparatus **400** to set absorbable rods **255**, **260**, but without their associated sleeves **80**, **85**, and **200**, **230**, respectively. In this case, at least one trocar would always remain positioned in graft ligament **250** until at least one absorbable rod **255**, **260** was positioned in the bone block.

If desired, it is also possible to practice the present invention using just one sleeve **80** and one trocar **100**, or just one sleeve **85** and one trocar **100**, or just one sleeve **200** and one trocar **210**, or without using sleeves and/or trocars at all.

Numerous further variations, alterations, modifications and other derivations of the present invention will occur and/or become obvious to those skilled in the art in view of the foregoing detailed description of the preferred embodiments of the present invention. Accordingly, it is to be understood that the foregoing specification and the appended drawings are intended to be illustrative only, and not as limiting of the invention.

The invention claimed is:

1. A trocar and trocar sleeve assembly, comprising:

a trocar, comprising:

an elongate shaft having a sharpened tip on a distal end thereof for penetrating bone; and

a pin disposed on a proximal portion of the elongate shaft spaced a distance from a proximal-most end of the elongate shaft and extending through a bore formed in the elongate shaft transverse to a longitudinal axis of the elongate shaft; and

a trocar sleeve, comprising:

an elongate shaft having an inner bore extending longitudinally therethrough; and

a collar formed on a proximal end of the elongate shaft of the trocar sleeve that includes a diagonally-extending slot formed therein for receiving the pin of the elongate shaft of the trocar when the trocar is inserted within the inner bore of the trocar sleeve such that the trocar and trocar sleeve are configured to move together in at least one direction when the pin is engaged within the slot.

2. The assembly of claim **1**, wherein the sharpened tip of the elongate shaft of the trocar extends distally from a distal end of the elongate shaft of the trocar sleeve when the pin of the trocar is engaged in the slot of the trocar sleeve.

3. The assembly of claim **1**, wherein the collar includes a bore therethrough that is in alignment with the bore extending through the elongate shaft of the trocar sleeve.

4. The assembly of claim **1**, wherein a proximal portion of the elongate shaft extends proximal to the collar when the pin is engaged within the slot.

5. The assembly of claim **1**, wherein the collar is formed on a proximal-most end of the elongate shaft of the trocar sleeve.

6. The assembly of claim **1**, wherein the elongate shaft of the trocar is removably and replaceably receivable within the inner bore of the elongate shaft of the trocar sleeve.

7. The assembly of claim **1**, wherein, when the trocar is inserted within the inner bore of the trocar sleeve, the elongate shaft of the trocar is longitudinally slidably movable within the inner bore.

8. The assembly of claim **1**, wherein the pin extends radially outward from opposed sides of the elongate shaft of the trocar.

9. The assembly of claim **1**, wherein the elongate slot is contained within a perimeter defined by the proximal end of the collar such that the elongate slot does not extend to the perimeter.

10. A trocar and trocar sleeve assembly, comprising:

a trocar, comprising:

an elongate shaft having a sharpened tip on a distal end thereof for penetrating bone; and

a pin disposed on the elongate shaft a distance distal from a proximal-most end of the elongate shaft, the pin extending transverse to a longitudinal axis of the elongate shaft; and

a trocar sleeve, comprising:

an elongate shaft having an inner bore extending longitudinally therethrough; and

a collar formed on a proximal end of the elongate shaft of the trocar sleeve that includes a diagonally-extending slot formed therein for receiving the pin of the elongate shaft of the trocar when the trocar is inserted within the inner bore of the trocar sleeve such that the trocar and trocar sleeve are configured to move together in at least one direction when the pin is engaged within the slot, and such that a proximal portion of the elongate shaft of the trocar sleeve extends proximal to the collar when the pin is engaged within the slot.

11. The assembly of claim **10**, wherein the collar is formed on a proximal-most end of the elongate shaft of the trocar sleeve.

12. The assembly of claim **10**, wherein the pin extends radially outward from the elongate shaft of the trocar sleeve.

13. The assembly of claim **12**, wherein the pin extends radially outward from opposed sides of the elongate shaft of the trocar sleeve.

14. The assembly of claim **10**, wherein the sharpened tip of the elongate shaft of the trocar extends distally from a distal end of the elongate shaft of the trocar sleeve when the pin of the trocar is engaged in the slot of the trocar sleeve.

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